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發明 ~~新型~~ 專利說明書

一、發明 ~~新型~~ 名稱	中文	用以支援節目訂看(VOD)之應用的前瞻性規劃
	英文	LOOK-AHEAD SCHEDULING TO SUPPORT VIDEO-ON-DEMAND APPLICATIONS
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四、中文發明摘要（發明之名稱：　用以支援節目訂看(VOD)之應用的前瞻性規劃　）

本案說明一種在可容納共用一共同資料流之多個觀眾之節目訂看型式服務中支援暫停-恢復的系統和方法。當節目伺服器接收來自觀眾之一的播放特定節目之執行要求時，其辨識並預留一前瞻性流。該前瞻性流是規劃成在預定時間間隔之後變為可用之另一節目流。當節目受到啟始時，同時自節目伺服器傳輸該節目之共同資料流至觀眾所在之接收設備。共同資料流之傳輸導致特定節目播放於觀眾之接收設備。當節目伺服器收到來自觀眾之一之暫停要求及隨後之後續恢復要求時，其經由前瞻性流而非共同資料流來傳輸節目。

英文發明摘要（發明之名稱：　LOOK-AHEAD SCHEDULING TO SUPPORT VIDEO-ON-DEMAND APPLICATIONS　）

A system and method of supporting pause-resume in a video-on-demand service of a type which can accommodate multiple viewers sharing a common data stream is described. When a video server receives a performance request from one of the viewers for showing a particular video, it identifies and reserves a look-ahead stream. The look-ahead stream is another video stream which is scheduled to become available after a predetermined time period. When the video is commenced, a common data stream for the video is concurrently transmitted from the video server to reception equipment at the viewers' locations. Transmission of the common data stream causes the particular video to be performed on the viewers' reception equipment. When the video server receives a pause request and then a subsequent resume request from one of the viewers, it transmits the video via the look ahead stream instead of the common data stream.

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（請先閱讀背面之注意事項再填寫本頁各欄）

五、發明說明（1）

發明背景

發明領域

本發明係關於集中型節目伺服器之訂看暫停-恢復的支援。

相關技術

暫停-恢復特色是VCR之最常見運作之一。近來，開發多媒體伺服器以支援節目訂看（VOD）應用日漸風行。在VOD環境中，經常會有為許多觀眾所要求之熱門節目。每一觀眾可在任何時刻獨立地暫停節目且稍後恢復觀看之需求已對每一播放之觀眾批次化造成困難。

在一支援訂看暫停-恢復之傳統方法中，提供一節目流給每一觀眾節目要求。對每一多媒體伺服器，磁碟所能支援之節目流數目有一最大值。該上限將以N_{MAX}來表示。因此上述之方法只能支援N_{MAX}觀眾。

在針對暫停-恢復問題之另一傳統方法中，"熱門"（流行）電影之節目流是規劃成他們啟始於相當接近之間隔。為回應收到來自觀眾之恢復指令（在收到暫停之後），伺服器指配相同電影之節目流之一給該觀眾，且該電影是規劃成在不久之未來會到達適當之恢復點。此一系統之一問題是觀眾在可自其暫停之點觀看該電影之前必須等到該流到達適當之恢復點。

II. 發明摘要

本發明之一目標是支援數目多於N_{MAX}之觀眾的暫停和快速恢復。

五、發明說明（2）

根據本發明之一實例提供在一種節目訂看服務支援暫停－恢復之系統和方法，且該種服務可容納共用一共同資料流之多個觀眾。當節目伺服器收到觀眾之一之播放特定節目的執行要求時，其辨識並預留一前瞻性流。該前瞻性流是規劃成在預定時間間隔之後變為可用之另一節目流。當節目啟始時，該節目之共同資料流同時自節目伺服器傳輸至觀眾所在之接收設備。共同資料流之傳輸導致該特定節目播放於該觀眾之接收設備。當節目伺服器收到來自觀眾之一的暫停要求以及然後隨後之恢復要求時，其經由前瞻性流而非共同資料流來傳輸該節目。

在一較佳實例中，具有〝暗視〞(look-aside)緩衝之〝前瞻性〞流規劃是用以支援數目多於N_{MAX}之觀眾。此系統無需利用磁碟之真實節目流容量來支援每一觀眾。

如果可使用儲存t單位播放時間的緩衝器，則二觀眾可共用相同之節目流，只要另一流在t單位時間之內變為可用。此無需至少t單位時間之真實流容量。前瞻性規劃利用目前正為另一播放所用之未來（前瞻性）流來支援觀眾以致其可在任何時間暫停和恢復。在前瞻性流變為可用之前，暫停和恢復播放是由原始流經由錯過內容之緩衝來支援。如果無足夠之緩衝器空間來支援前瞻性規劃，則使用預留流。

預留流是伺服器之其他未用的流容量。當指配一預留流時，多媒體系統之可用流容量減少一。藉由預留流，正與其他觀眾共用共同資料流之觀眾可在任何時間暫停。當觀

五、發明說明（3）

眾要恢復時，預留流變為觀眾要觀看之有效流。

當相關於一前瞻性流之節目播放結束時，如果可發現將在t單位時間之內結束之另一播放或預留流，則可辨識一新前瞻性流且結束之前瞻性流可用以規劃其他觀眾。所以觀眾在播放期間可由一系列不同之前瞻性流來支援。

因此每一觀眾是由播放節目之真實流，某一前瞻性流，或預留流，來支援。給定播放之每一真實流或預留流可支援另一播放之前瞻性流。由於前瞻性流之觀眾可暫停以致真正之結束時間不確定這項事實而有一額外程度之複雜性。若要避免此問題，則一流，一旦被選為前瞻性流，不得暫停。相對地，當觀眾暫停時，該流要受到緩衝。然後，當觀眾要恢復時，其觀看來自緩衝器之節目。一旦觀眾可自緩衝器取得節目之剩餘部份，則對該節目將無進一步之流要求。該觀眾之緩衝器內含直到觀看結束才會受到釋放。

III.附圖簡單說明

圖1是一多媒體伺服器之方塊圖；

圖2是（暗視）緩衝器狀態之方塊圖；

圖3展示流狀態表；

圖4展示一節目要求處理範例之時間線；

圖5是根據本發明之一實例之圖1前瞻性規劃器之總圖的流程圖；

圖6a和6b是前瞻性規劃器工作之更詳細流程圖；

圖7是暫停運作之更詳細流程圖；

五、發明說明（ 4 ）

圖 8 是恢復運作之更詳細流程圖；

圖 9 是流結束運作之更詳細流程圖；

圖 10是觀看結束運作之更詳細流程圖；

圖 11是前瞻性流切換過程之更詳細流程圖。

出現於多於一附圖之相同參考號碼表示相同之組件。

IV. 較佳實例之詳細說明

圖 1 是根據本發明之一實例之節目訂看系統的方塊圖。在下列說明中，假設在節目訂看系統中客戶 1 經由通訊網路 3 向節目伺服器 2 提出要求。電影（節目）儲存於磁碟 5 。伺服器 2 包含用以暫時儲存電影來處理短暫停要求之記憶體緩衝器 6 。節目伺服器 2 也包含在主控制程式 (mcp) 8 控制之下執行工作之處理器 7（cpu）。節目伺服器可利用具有足以支援所要數目之節目流之效能的任何處理器來加以建構。例如，小容量之節目伺服器可利用 RISC System/6000（RS/6000）系統來建構而更大容量之節目伺服器可利用 ES/9000 系統來建構（此二系統皆可向國際商業機器公司，Armonk，New York，購得）。通訊網路 3 可為，例如，光纖網路。客戶 1 是由 set-top 箱來支援；而該箱使客戶們可藉由網路 3 來傳輸指令至伺服器 2。

根據本發明之一實例，諸工作之一是前瞻性規劃器 9 。客戶可要求啟始，中止，暫停和恢復電影。個別之客戶要求是由客戶規劃器 40來處理。前瞻性規劃器 9 試圖藉由結合在時間上相近之相同電影要求來保留伺服器資源而同時允許每一客戶個別地暫停和恢復。

五、發明說明（5）

前瞻性規劃器9維持緩衝器狀態表4，而該緩衝器狀態表追蹤記憶體緩衝器6之使用。現在請參看圖2，（暗視）記憶體緩衝器狀態將受到說明。每一緩衝器塊區可在三狀態之一：預留（reserved），使用中（in-use），和可用（available）。下文將對此更詳細加以解釋，在電影之規劃期間，可將緩衝器置於〝預留〞狀態來支援暫停-恢復。當儲存節目流於〝預留〞緩衝器時，該緩衝器轉變為〝有效〞（使用中）狀態。非〝預留〞或〝有效〞之緩衝器可供未來指配之用。

前瞻性規劃器也維持流狀態表11，而現在將參照圖3來說明該流狀態表。多媒體伺服器只可支援固定數目之流。如果一流支援節目之真實播放，其被視為〝有效〞。如果一流是預留來支援一播放之同時觀眾的暫停-恢復，其被視為〝預留〞如果一流容量不是〝有效〞也不是〝預留〞，其可供未來播放之用。

圖3展示執行簿記之一種方法。對每一流，有效，預留或無之狀態受到記錄。在有效欄301和預留欄302無記錄狀態（無）表示該流是可供使用。對預留流，有關播放節目之對應有效流的資訊也記錄於〝預留〞欄302。如果一流是標示為由一有效流服務之另一播放之觀眾的前瞻性流，辨識該有效流之資訊是提供於〝前瞻性〞欄304。播放於有效流之節目的識別（ID）是記錄於節目識別欄306。

例如，在圖4中，假設對節目A之三節目要求受規劃為時間t_0且在那一刻無其他有效流。流1是選為有效流而流

五、發明說明（6）

2 和 3 是標示為流 1 之同時觀眾的預留流。（參看圖 3 之流 2 和 3 的預留欄）。在時間 t_1 對節目 B 之二節目要求受到規劃。假設流 1 在 t 單位時間之內可結束且有足夠之緩衝器來支援流 1 充當前瞻性流。我們可選擇流 4 做為有效流且使用流 1 做為前瞻性流。（參看圖 3 之流 1 的前瞻性欄）。請注意此第二群組（節目 B）之觀眾不是流 1 之目前觀眾。他們只是使用流 1（其目前攜帶節目 A）做為前瞻性流來支援暫停- 恢復運作。因此，流 1 之觀眾總是代表目前正在觀看節目 A 之第一群組之觀眾。如果對節目 C 之另外四要求隨後立即受到規劃，流 5 可做為有效流而流 2 和 3 做為前瞻性流，假設有足夠之緩衝器。此外，需要流 6 做為預留流。（參看圖 3 之流 2 的前瞻性欄和流 6 的預留欄。）圖 3 展示此時之流狀態，其中有 9 觀眾正在佔用 6 流容量。

假設多媒體系統具有暗視用途之大小 B 的緩衝器以及 N_{MAX} 之流容量。讓 N_{RESRV} 是系統之預留流的數目且 N_{ACT} 是播放節目之有效流的數目。該 B_{RESRV} 是預留之暗視緩衝器的數量且 B_{USE} 是目前使用中之暗視緩衝器的數量。我們進一步假設每一單位時間之播放需要 K 位元之資料。

每一次選擇一節目來播放時，如果 N_W 客戶在等該節目，下列程序決定可受到規劃來允許暫停- 恢復之觀眾的最大數目，C.假設緩衝器受到限制，此程序盡可能使用最多之前瞻性流，且藉由預留流來支援剩餘之觀眾。更明確的說

五、發明說明（7）

1. 首先，假設目前緩衝器之使用已知，決定可支援之額
外前瞻性流的最大數目。此稱為N_{LAHEAD} 且是下列二
數量之最小值，

- 假設無暫停，在下面t 單位時間內會結束之節目
流（尚未標示為前瞻性流），的數目，其中t 是
預先辨識之運作參數且是由可用以支援暫停－恢
復之緩衝器空間數量來決定。有潛在之前瞻性流
。
- 緩衝器之目前狀態可支援之額外前瞻性流的數目
。讓我們基於潛在前瞻性流之結束剩餘時間來將
他們排序，假設無暫停。從緩衝之觀點來看，可
基於該次序來選擇前瞻性，亦即基於他們之結束
時間來選擇前瞻性流。假設第 i 個潛在前瞻性流
具有結束剩餘時間$t\alpha_i$，如果被選中的話其將需
要預留大小為$tK\alpha_i$ 之緩衝器。如果潛在前瞻性
流之目前觀眾進入暫停模式則需要該緩衝器數量
來保存節目內容至結束。（其大至足以串流播放
之剩餘部份進入緩衝器，即使是在立即暫停之最
壞情況）。如果x 前瞻性流受到選擇，則將需要
$xtK\bar{\alpha}$ 數量之額外預留緩衝器來處理他們之相關
觀眾的暫停，其中$\bar{\alpha}t$ 是最先x 潛在前瞻性流之
平均結束剩餘時間，亦即：

$$\bar{\alpha}=\left(\sum_{i=1}^{x}\alpha_i\right)/x$$

五、發明說明（８）

此外，需要預留tK數量之緩衝器空間來在前瞻性流變為可用之前支援新觀眾群組（目前正等候規劃）之短暫停。因此，若x前瞻性流受到選擇，則需要預留之緩衝器的總數量是（tK+xtKα）。因此，從緩衝器之觀點來看可支援之前瞻性流的最大數目是滿足緩衝器限制之最大x值。

2. 如果此最大數目（x）是大於Nw-1，所有這些要求觀眾皆可藉由用以播放節目之一真實流，及Nw-1前瞻性流，來規劃。在此情形之下，C等於Nw。

3. 否則，所使用之前瞻性流的數目是N_{LAHEAD}。我們需要獲得一些流容量來置於預留模式以規劃不為前瞻性流所支援之額外觀眾。可獲得之預留流必須小於可用流之數目，N_{AVAIL}，而N_{AVAIL}等於$N_{MAX}-(N_{RESRV}+N_{ACT})$。如果可將$Nw-N_{LAHEAD}-1$或更多流置於預留模式，所有要求觀眾仍可受到規劃，亦即C等於Nw。否則，C將是$N_{AVAIL}+N_{LAHEAD}$。

讓D是所使用之前瞻性流的數目。然後我們將設定B_{RESRV}等於$tK+DK\alpha+B_{RESRV}$且使N_{ACT}增加一。如果使用預留流，N_{RESRV}也會因而增加。請注意當預留緩衝器實際用以支援暫停動作時B_{USE}將增加。（B_{RESRV}將減少相同數量）。當無需此緩衝器時其將受到釋放。

步驟1之緩衝器限制可表示成$\Theta(tK+xtK\alpha+B_{RESRV})<(B-B_{USE})$，其中Θ（theta）是調整參數。設定Θ等於一保證暫停之觀眾將總是可在無延遲之下回復。事實上，並非

五、發明說明（9）

所有觀眾將在相同時間暫停，所以Θ可設為較低值而仍可使回復觀眾需要等候之機率維持在非常低。同樣地，N_{AVAIL}可重新定義為$N_{MAX}-(\Theta' N_{RESRV}+N_{ACT})$，其中Θ'是另一調整參數。請注意在保證無延遲恢復之情形下，Θ'是設為一。

指配之前瞻性流可受到延遲。若有額外之ΘtK數量的緩衝器可在下面t單位時間之內受到預留，則可允許前瞻性流在t單位時間之後變為可用。此規則可重覆應用。

當標示為前瞻性流之流結束時，如果可發現另一前瞻性流來取代該流（亦即在t單位時間之內結束），則可利用新的可用流容量來規劃新的觀眾要求。否則其變為預留流。如果前瞻性流在t+w單位時間之後將變為可用，則預留流可在w單位時間之後由該前瞻性流來取代。然後其可規劃為供其他播放所用。

另一改善輸出量之最佳方法是允許恢復流與稍後播放之真實流相匯合。但是仍需要前述之適當前瞻性流來支援未來之額外暫停。

現在請參看圖5，其展示根據本發明之一實例之規劃方法總圖的流程圖。節目要求抵達示於步驟10。在步驟15，檢查可用之流容量。如果無可用之流容量，步驟20受到執行而抵達之節目要求是置於要求等候佇列。否則，如果有可用之流容量，步驟25-40受到執行。在步驟25，節目要求或諸要求受到規劃。規劃程序之細節示於圖3。一旦節目受到規劃，每一觀眾可在任何所要時間暫停且然後恢復

五、發明說明（10）

，如用於暫停運作之步驟30以及用於恢復之步驟35所示。

現在請參看圖6a和6b，規劃運作之細節受到更詳細地展示。在步驟50，假設每一次選擇一電影來播放時，有Nw客戶在等候該電影。在步驟55，可標示為前瞻性流之可用流的數目受到決定。這是在假設無暫停要求之下可在下面t單位時間內結束之流，尚未標示為前瞻性流，的數目。在步驟60，給定之緩衝器大小可支援之前瞻性流的最大數目(N_{LAHEAD})受到決定。

在步驟65，比較N_{LAHEAD}與Nw-1。如果N_{LAHEAD}大於Nw-1，所有要求可共用一節目流，其中另外Nw前瞻性流是用以支援暫停要求，如步驟70所示。在步驟75，將支援前瞻性規劃所需數目之緩衝器置於預留模式。

回到步驟65，如果給定之緩衝器大小可支援之前瞻性流的最大數目小於Nw-1，則無足夠之前瞻性流，因此必須將一些節目流容量變成預留模式。步驟80決定目前可用（亦即非播放或預留）之節目流的數目。在步驟85，比較可用節目流之數目與支援該節目未決觀眾之需求。如果有足夠之可用節目流，步驟90和95受到執行。否則，步驟100和105受到執行。在步驟90和100，分別規劃適當數目之要求以觀看節目播放。在步驟95和105，分別使適當數目之節目流成為預留模式。在步驟110，使支援前瞻性規劃所需之緩衝器空間數量成為預留模式。在步驟115和120，規劃之簿記結束。

現在請參看圖7，暫停運作之細節受到更詳細地展示。

五、發明說明（11）

步驟130 顯示暫停要求到達節目伺服器。在步驟135 ，檢查該觀眾是否可由前瞻性流來支援。如果該觀眾可由前瞻性流來支援，如步驟140 所示，預留緩衝器是用於為暫停之觀眾暫時緩衝最多t 單位時間之錯過內容。在步驟145 ，暫停間隔受到檢查。如果該間隔超過極限，在步驟150 如果無其他觀眾在使用該緩衝器則釋放該緩衝器。

如果，在步驟135 ，觀眾無法由前瞻性流來支援，則在步驟155 進一步檢查該支援流是否標示為另一觀眾之前瞻性流。如果是的話，在步驟160 ，該節目流將繼續串流節目進入緩衝器直到結束。圖9 解釋步驟170 所示之流結束運作。在步驟155 ，如果該流未標示為前瞻性，可如步驟175 所示將該流停止。

現在請參看圖8 ，我們檢查恢復運作之細節。在步驟200 ，檢查是否緩衝器有恢復點。如果是的話，如步驟205 所示，觀眾藉由緩衝器來恢復觀看。否則，如步驟210 所示，將使預留流成為真實播放流來支援恢復之觀眾。

現在請參看圖9 ，其展示流結束運作之細節。在步驟220 ，當節目流結束時，規劃器決定是否此流或任何其他相關之預留流已標示為前瞻性流。對標示為前瞻性流之每一流，如步驟230 所示，規劃器決定是否另一流可受到辨識及切換成為前瞻性流。圖8 對此詳細加以說明。如果另一流可切換成為前瞻性流，步驟235 和240 受到執行。在步驟235 ，該流是標示為新的前瞻性流以取代結束節目流

五、發明說明（12）

且在步驟240，結束流受到釋放成為可用流且如果有等候之節目要求則可啟始規劃新節目要求之過程。（圖6說明流規劃過程）。在步驟230，如果無其他流可切換成為前瞻性流，步驟245和250受到執行。在步驟245，使結束流成為預留流，而在步驟250，適當之簿記受到執行。

現在請參看圖10，我們檢查觀看結束運作之細節。請注意觀看結束可遲於流結束，因為在暫停期間，節目流可繼續並儲存於緩衝器。在步驟280，如果另一觀眾無需緩衝器空間則為結束觀眾所用或預留之所有緩衝器空間皆受到釋放。在步驟285，檢查同時之流結束。如果有的話，描述於圖6之適當動作受到執行。

最後現在請參看圖11，切換前瞻性流之過程的細節將受到說明。圖8是圖6步驟230之更詳細流程圖。在步驟300，讓ε（epsilon）是前瞻性流相對於真實播放流之延遲。在步驟305，檢查ε之值。如果其不等於零，在步驟310，檢查可用緩衝器之數量。如果在某一額外指配（Θ tKε之數量）之後仍有足夠之緩衝器（大於B_{MIN}），則步驟315和320受到執行。在步驟315，執行該額外緩衝器之指配，而在步驟320，前瞻性間隔設為t。在步驟335，檢查是否任何尚未標示為前瞻性流之流可在下面t單位時間之內終止，假設暫停不會出現。（如果有的話，在步驟235，選擇在假設無暫停之下最早終止之流做為切換之前瞻性流）。

回到步驟310，如果在某一額外指配（Θ tKε之數量）

五、發明說明（13）

之後沒有足夠之緩衝器（不大於B_{MIN}），則無額外緩衝器受到預留且步驟325和335受到執行。在步驟325，前瞻性間隔設為$t-\varepsilon$。

回到步驟305，如果ε之值等於零，則步驟330和335受到執行。在步驟330，前瞻性間隔設為t。

因為已藉由較佳實例來說明本發明，熟悉本技術領域者將可想出多種修正和改善。因此，應瞭解的是較佳實例是做為示範而非限制。本發明之範圍是由附加之申請專利範圍來加以定義。

六、申請專利範圍

1. 一種在一節目訂看系統中支援暫停-恢復的方法，其型式為可容納共用一共同資料流之多個觀察，其包含下列步驟：

接收來自觀眾之一之播放特定節目的執行要求；

為回應該執行要求，辨識並預留前瞻性流，而該前瞻性流是規劃成在預定時間間隔之後變為可用之另一節目流；

同時傳輸共同資料流自節目伺服器至多個觀眾所在之接收設備，而該資料流之傳輸導致該特定節目播放於該接收設備；

在節目伺服器上接收來自觀眾之一之暫停要求及隨後之恢復要求；及

為回應恢復要求，經由前瞻性流而非共同資料流來傳輸該特定節目。

2. 根據申請專利範圍第1項之方法，其中在無觀眾啟始暫停要求之下經過一段時間間隔之後不同之前瞻性流受到辨識。

3. 根據申請專利範圍第1項之方法，其中為回應執行要求而指配一預留流給觀眾之一且當前瞻性流受到辨識時該預留流受到釋放。

4. 根據申請專利範圍第1項之方法，其中觀眾之一被指配足夠之緩衝器空間以緩衝共同節目流一段預定之時間間隔。

5. 根據申請專利範圍第1項之方法，其包含緩衝節目資料

六、申請專利範圍

流以回應來自觀眾之暫停要求的進一步步驟，因此一定流容量可支援之觀眾數目獲得增加。

6. 一種用以在一節目訂看系統中支援暫停-恢復的系統，且該型式之節目訂看系統可容納共同一共同資料流之多個觀眾，其包含下列步驟：

用以接收來自觀眾之一之播放特定節目之執行要求的接收裝置；

辨識裝置，耦接至接收裝置且回應該執行要求之接收，用以辨識並分配前瞻性流，而該前瞻性流是規劃成在預定時間間隔之後變為可用之另一節目流；

用以同時傳輸共同資料流自節目伺服器至多個觀眾所在之接收設備的傳輸裝置，且該資料流之傳輸導致該特定節目播放於該接收設備；

用以接收來自觀眾之一之暫停要求及隨後之恢復要求的暫停／恢復裝置；及

取代裝置，用以回應恢復要求，經由前瞻性流而非共同資料流來傳輸該特定節目。

7. 根據申請專利範圍第6項之系統，其中在無觀眾啟始暫停要求之下經過一段時間間隔之後不同之前瞻性流受到辨識。

8. 根據申請專利範圍第6項之系統，其中當前瞻性流受到辨識時指配受到釋放之一預留流給該觀眾。

9. 根據申請專利範圍第6項之系統，其中取代裝置不會藉由前瞻性流來傳輸特定節目，除非是在大於離暫停要求

六、申請專利範圍

之一預定時間間隔之下收到恢復要求，且進一步包含緩衝器裝置，用以回應暫停要求，緩衝共同節目流一段預定時間間隔以及緩衝器存取裝置，用以藉由緩衝器裝置來服務觀眾之一，如果是在預定時間間隔之內收到恢復要求。

10. 一種在一節目訂看服務中支援暫停-恢復的方法，其型式訂為可容納共用一共同資料流之多個觀眾，其包含下列步驟：

接收來自觀眾之一之播放特定節目的執行要求；

同時傳輸共同資料流自節目伺服器至多個觀眾所在之接收設備，而該資料流之傳輸導致該特定節目播放於該接收設備；

在節目伺服器上接收來自觀眾之一之暫停要求及隨後之恢復要求；及

為回應恢復要求，經由啟始攜帶特定節目之另一流而非共同資料流的傳輸來為觀眾之一播放該特定節目。

11. 根據申請專利範圍第10項之方法，其中該特定節目是啟始於觀眾之一提出暫停要求之處。

12. 根據申請專利範圍第10項之方法，其包含緩衝節目資料流以回應來自觀眾之暫停要求的進一步步驟，因此一定流容量可支援之觀眾數目獲得增加。

13. 根據申請專利範圍第10項之方法，其包含下列步驟以回應執行要求：辨識並分配前瞻性流，且該前瞻性流是規劃成在預定時間間隔之後變為可用之另一節目流；以及

六、申請專利範圍

，利用該前瞻性流做為另一流。

14. 根據申請專利範圍第10項之方法，其中另一流是自節目伺服器之預留容量分配而得之預留流。

15. 根據申請專利範圍第10項之方法，其進一步包含下列步驟：指配緩衝器空間以緩衝共同節目流一段預定之時間間隔，且當觀眾之一在該預定之時間間隔之前恢復時，藉由緩衝器空間，而非藉由另一流，來提供特定節目給觀眾之一。

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圖 1

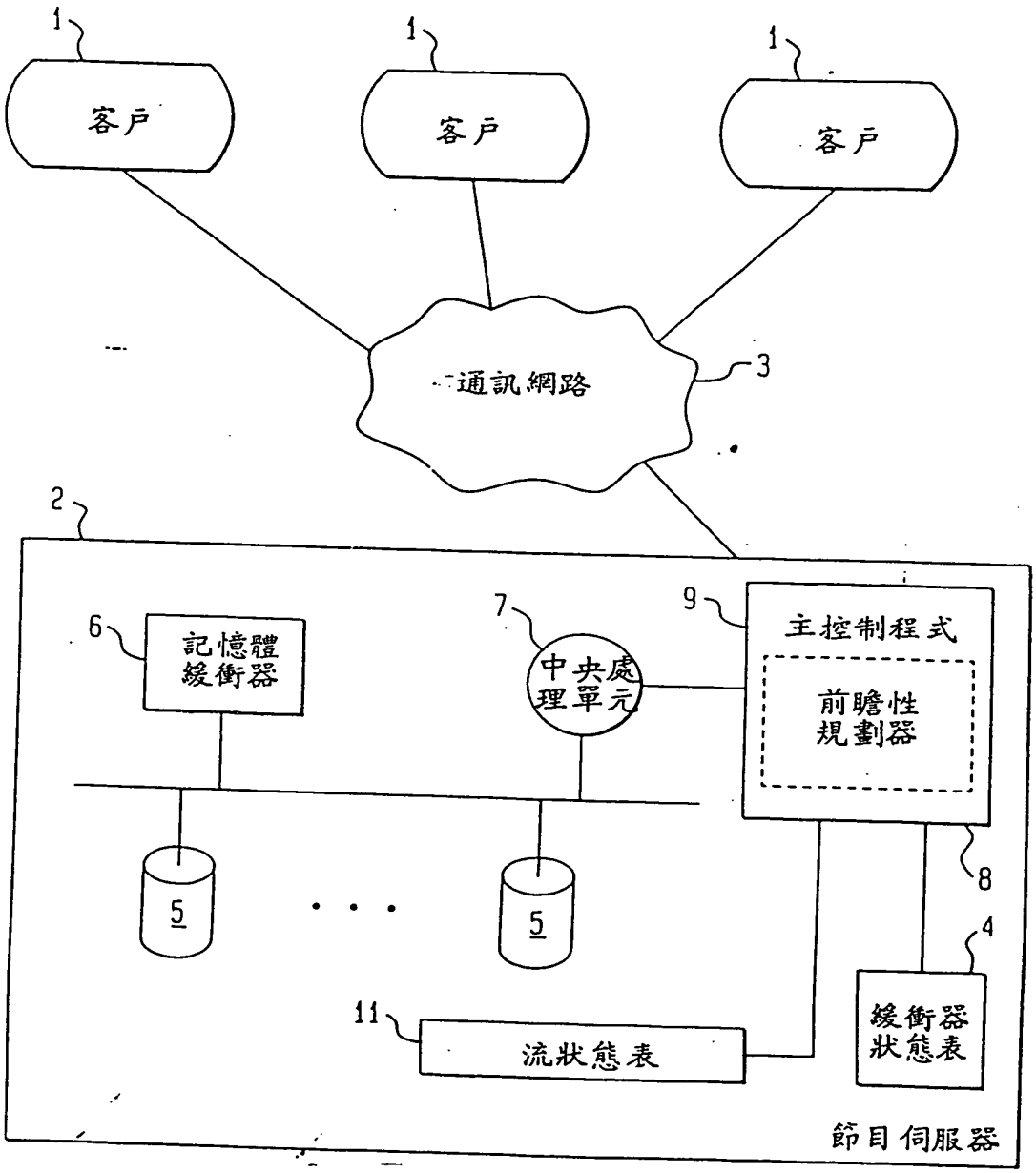
1
客戶
1
客戶
1
客戶
通訊網路
3
2
6
記憶體緩衝器
7
中央處理單元
9
主控制程式
前瞻性規劃器
8
5
5
4
緩衝器狀態表
11
流狀態表
節目伺服器

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圖 2

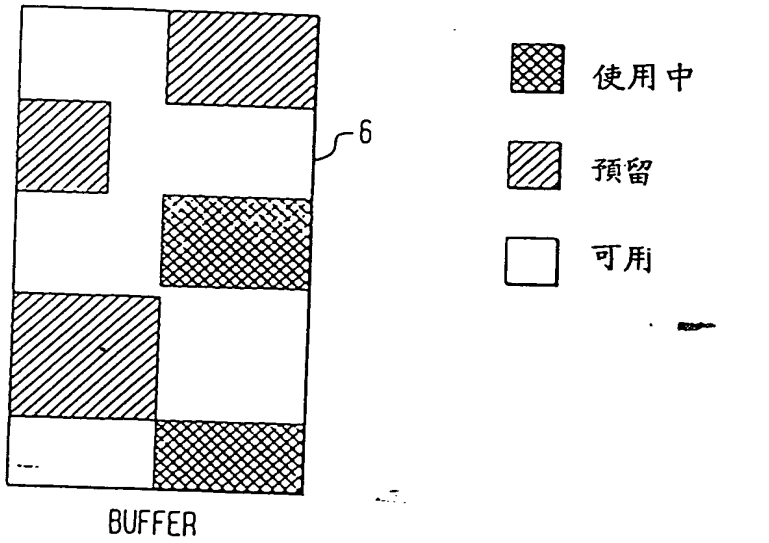

圖 3

流識別	有效 (301)	預留 (302)	前瞻性 (304)	節目識別 (306)
1	Y		4	A
2		Y 1	5	
3		Y 1	5	
4	Y			B
5	Y			C
6		Y 5		
7				
8				
9				
10				

11

圖 4

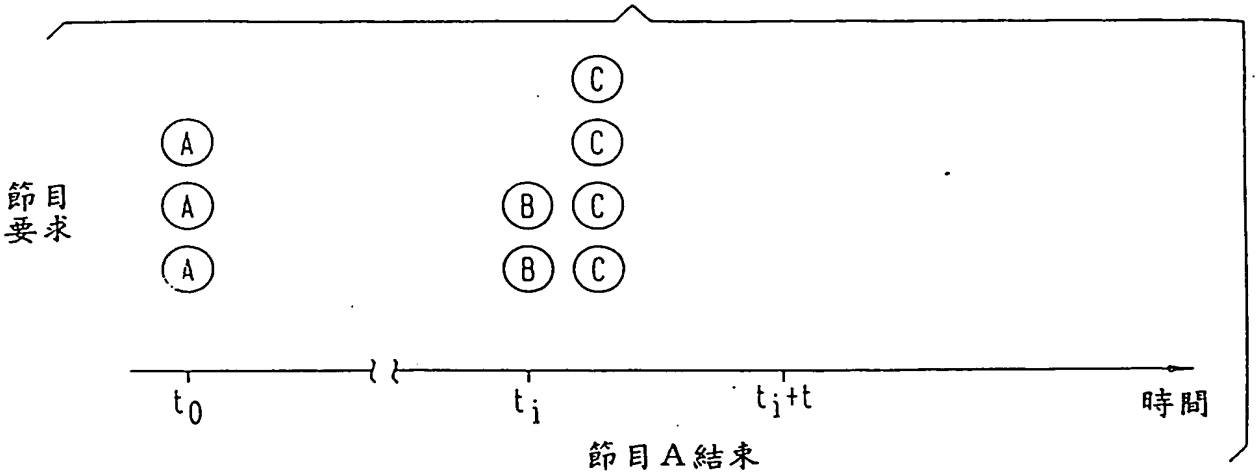
節目要求
A
A
A
B
C
B
C
C
C
t_0
t_i
t_i+t
時間
節目A結束

圖 5

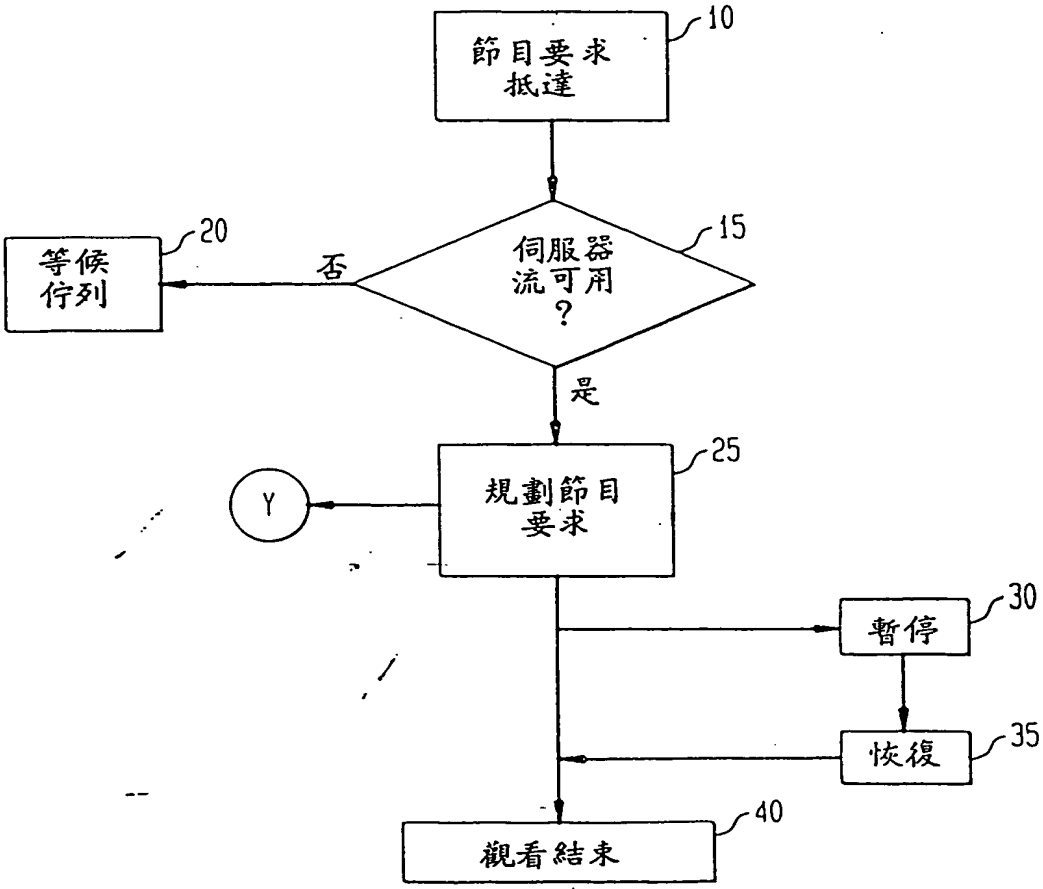
節目要求抵達
10
伺服器流可用？
15
否
等候佇列
20
是
規劃節目要求
25
Y
暫停
30
恢復
35
觀看結束
40

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圖 6A

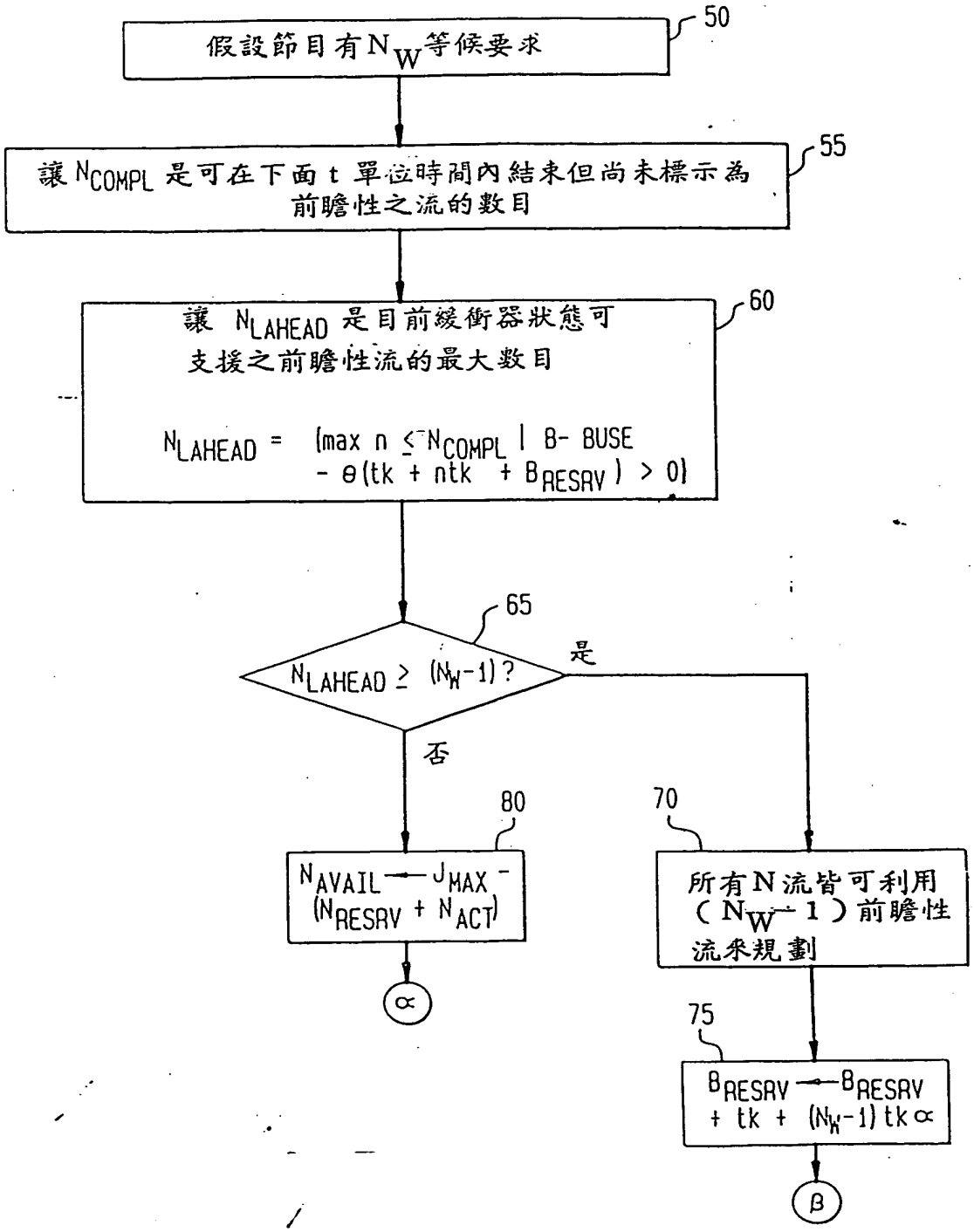
假設節目有N_W等候要求
50
讓N_{COMPL}是可在下面t單位時間內結束但尚未標示為前瞻性之流的數目
55
讓 N_{LAHEAD} 是目前緩衝器狀態可支援之前瞻性流的最大數目
$N_{LAHEAD} = \{\max n \leq N_{COMPL} \mid B - BUSE - \theta(tk + ntk + B_{RESRV}) > 0\}$
60
$N_{LAHEAD} \geq (N_W-1)$?
65
是
否
$N_{AVAIL} \leftarrow J_{MAX} - (N_{RESRV} + N_{ACT})$
80
所有N流皆可利用（N_W-1）前瞻性流來規劃
70
$B_{RESRV} \leftarrow B_{RESRV} + tk + (N_W-1)tk\alpha$
75
α
β

圖 6B

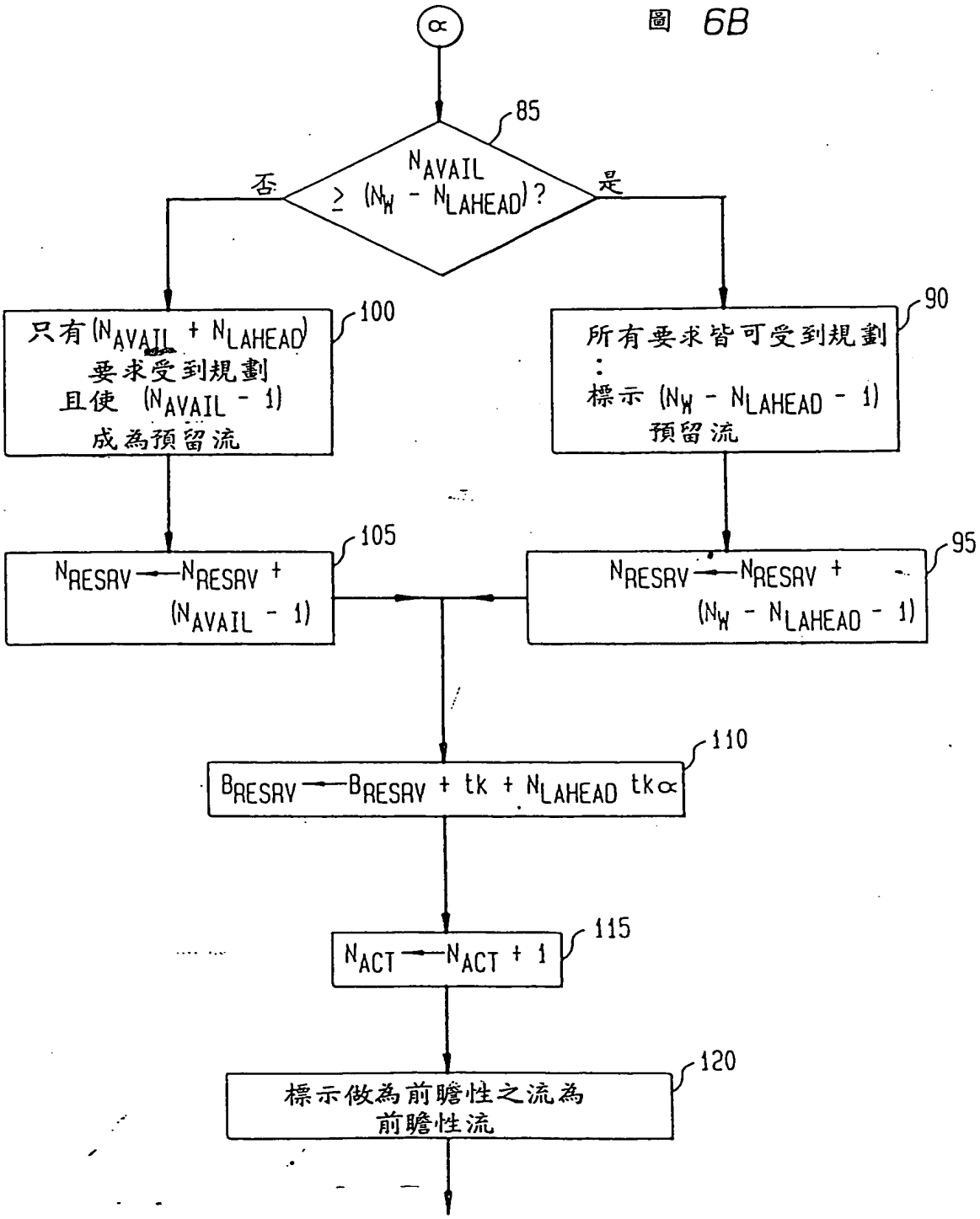
∝
85
$N_{AVAIL} \geq (N_W - N_{LAHEAD})$?
否
是
只有(N_{AVAIL} + N_{LAHEAD})要求受到規劃且使(N_{AVAIL} - 1)成為預留流
100
所有要求皆可受到規劃
:
標示(N_W - N_{LAHEAD} - 1)預留流
90
$N_{RESRV} \leftarrow N_{RESRV}$ + (N_{AVAIL} - 1)
105
$N_{RESRV} \leftarrow N_{RESRV}$ + (N_W - N_{LAHEAD} - 1)
95
$B_{RESRV} \leftarrow B_{RESRV}$ + tk + N_{LAHEAD} tk∝
110
$N_{ACT} \leftarrow N_{ACT}$ + 1
115
標示做為前瞻性之流為前瞻性流
120

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圖 7

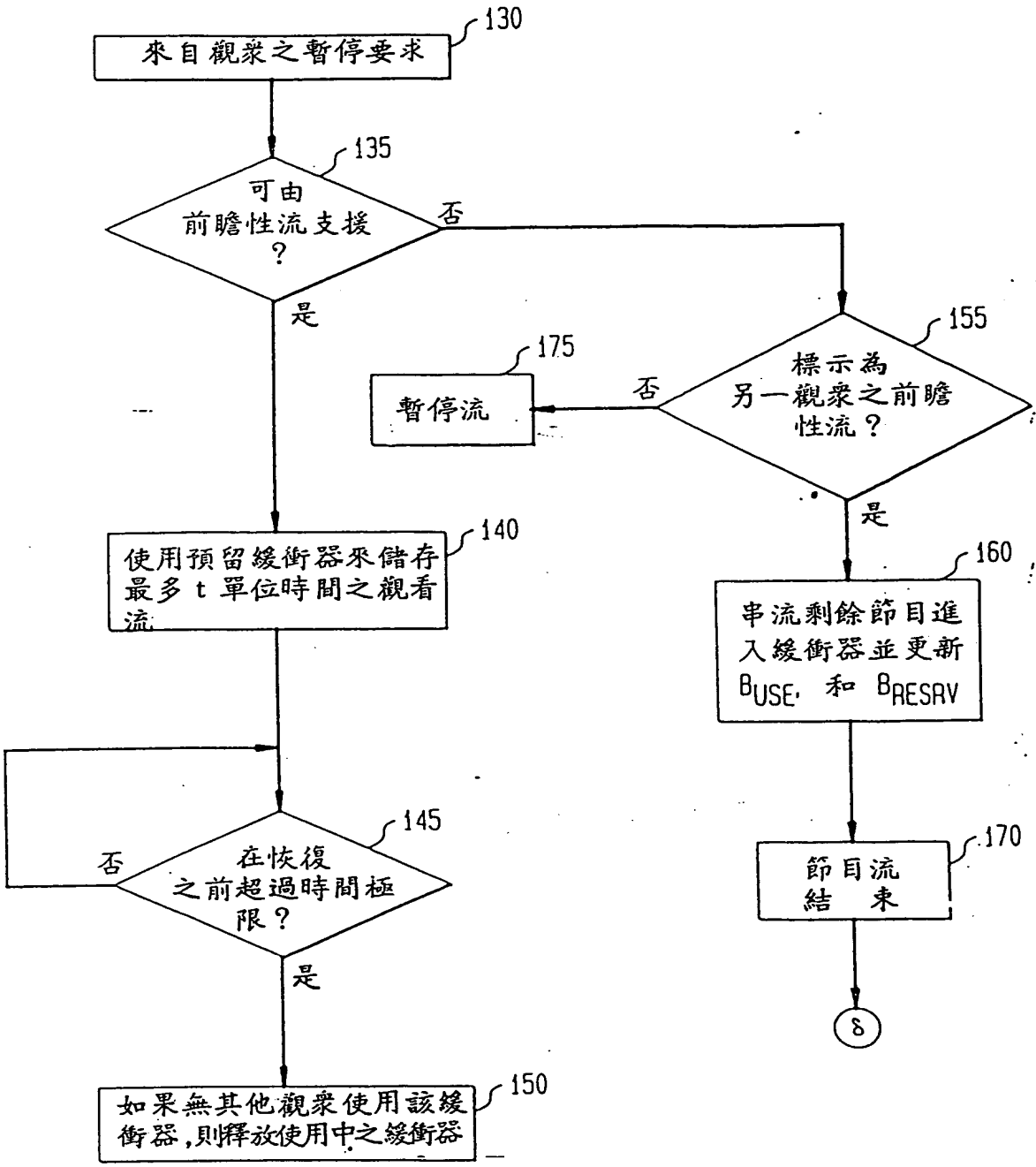
130
來自觀眾之暫停要求
135
可由前瞻性流支援？
否
是
155
標示為另一觀眾之前瞻性流？
否
175
暫停流
是
140
使用預留緩衝器來儲存最多 t 單位時間之視看流
160
串流剩餘節目進入緩衝器並更新 B_{USE} 和 B_{RESRV}
145
在恢復之前超過時間極限？
否
是
170
節目流結束
8
150
如果無其他觀眾使用該緩衝器，則釋放使用中之緩衝器

圖 8

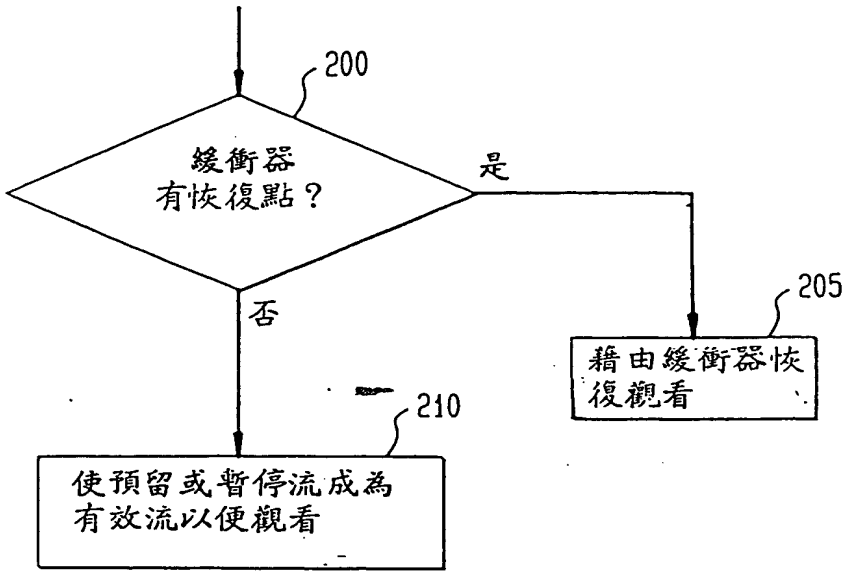

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圖 9

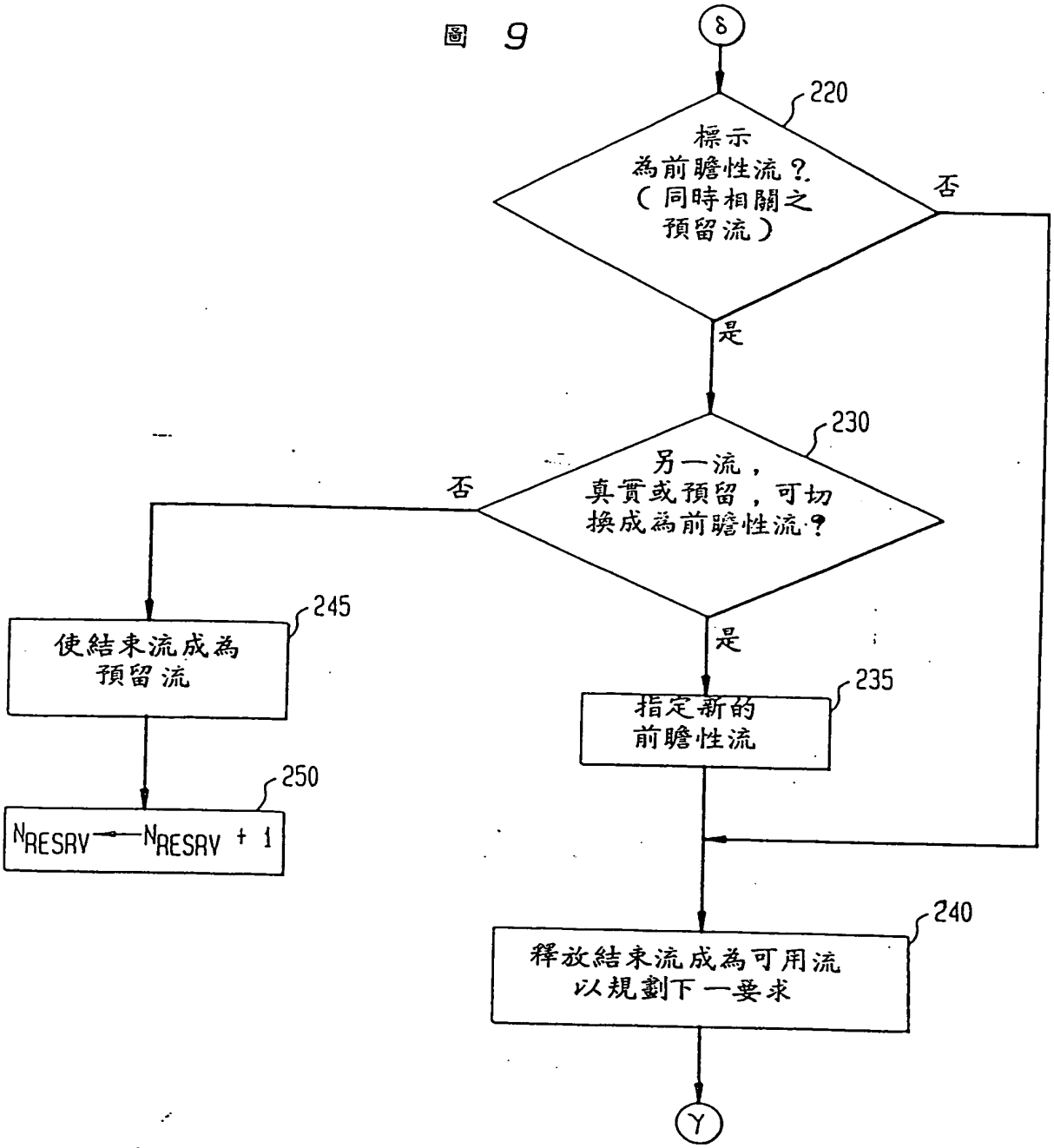

δ
220
標示
為前瞻性流？
（同時相關之
預留流）
否
是
230
另一流，
真實或預留，可切
換成為前瞻性流？
否
是
245
使結束流成為
預留流
235
指定新的
前瞻性流
250
NRESRV ← NRESRV + 1
240
釋放結束流成為可用流
以規劃下一要求
γ

圖 10

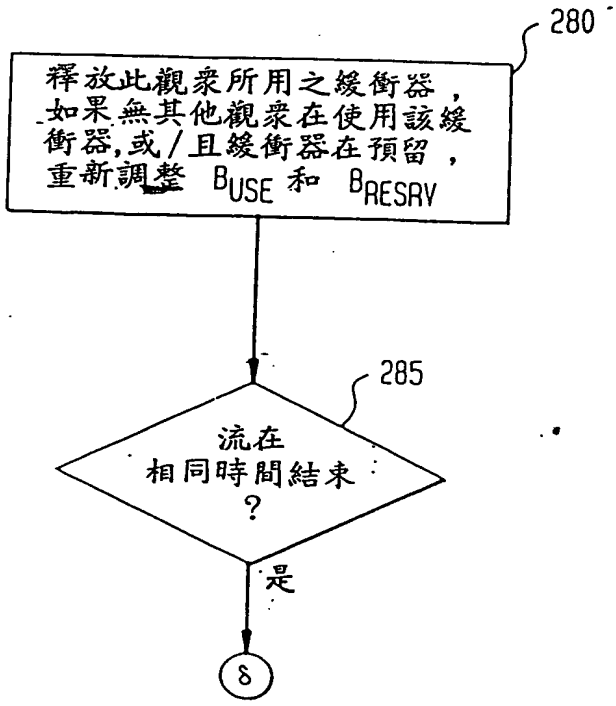
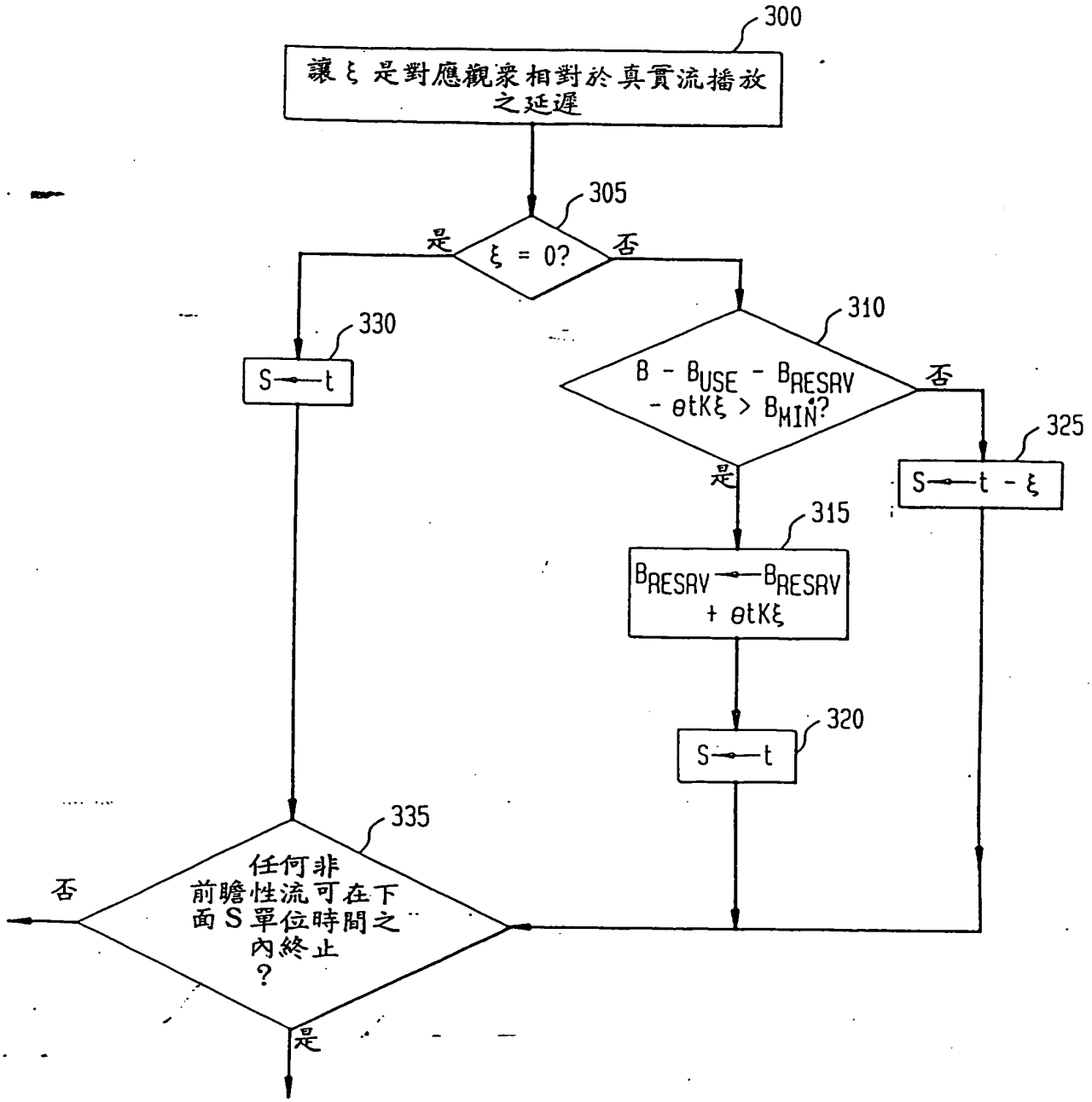

280
釋放此觀衆所用之緩衝器，如果無其他觀衆在使用該緩衝器,或/且緩衝器在預留，重新調整 B_{USE} 和 B_{RESRV}
285
流在相同時間結束？
是
δ

圖 11


300
讓ξ是對應觀眾相對於真實流播放之延遲
305
ξ = 0?
是
否
330
S—t
310
B - BUSE - BRESRV - θtKξ > BMIN?
否
325
S—t - ξ
是
315
BRESRV—BRESRV + θtKξ
320
S—t
335
任何非前瞻性流可在下面S單位時間之內終止?
否
是

8310-570

LOOK-AHEAD SCHEDULING TO SUPPORT VIDEO-ON-DEMAND APPLICATIONS

ABSTRACT OF THE DISCLOSURE

A system and method of supporting pause-resume in a video-on-demand service of a type which can accommodate multiple viewers sharing a common data stream is described. When a video server receives a performance request from one of the viewers for showing a particular video, it identifies and reserves a look-ahead stream. The look-ahead stream is another video stream which is scheduled to become available after a predetermined time period. When the video is commenced, a common data stream for the video is concurrently transmitted from the video server to reception equipment at the viewers' locations. Transmission of the common data stream causes the particular video to be performed on the viewers' reception equipment. When the video server receives a pause request and then a subsequent resume request from one of the viewers, it transmits the video via the look ahead stream instead of the common data stream.

LOOK-AHEAD SCHEDULING TO SUPPORT VIDEO-ON-DEMAND APPLICATIONS

Background of the Invention

Field of the Invention

The present invention relates to the support of on-demand pause-resume in a central video server.

Related Art

The feature of pause-resume is one of the most common operations in VCR. Recently, it has become increasingly popular to develop multimedia servers to support video-on-demand (VOD) applications. In a VOD environment, there are often hot videos which are requested by many viewers. The requirement that each viewer can independently pause the video at any instance and later resume the viewing has caused difficulties in batching of viewers on each showing.

In one conventional approach to support on-demand pause-resume, one video stream is provided for each viewer video request. For each multimedia server, there is a maximum number of video streams to the disks that can be supported. This upper limit will be referred to as N_{MAX}. Thus, the above-described approach can only support N_{MAX} viewers.

In another conventional approach to the pause-resume problem, video streams for "hot" (popular) movies are scheduled such that they commence at fairly close intervals. In response to receipt of a resume commend from a viewer

(after having received a pause) the server assigns to the viewer one of the video streams for the same movie which is scheduled to reach the proper resume point in the near future. One problem with such a system is that the viewer must wait until a stream reaches the proper resume point before the movie can be viewed from the point at which the viewer paused.

II. Summary Of The Invention

It is an object of the invention is to support pause and quick resume for a larger number of viewers than N_{MAX}.

In accordance with an embodiment of the present invention there is provided a system and method of supporting pause-resume in a video-on-demand service of a type which can accommodate multiple viewers sharing a common data stream. When a video server receives a performance request from one of the viewers for showing a particular video, it identifies and reserves a look-ahead stream. The look-ahead stream is another video stream which is scheduled to become available after a predetermined time period. When the video is commenced, a common data stream for the video is concurrently transmitted from the video server to reception equipment at the viewers' locations. Transmission of the common data stream causes the particular video to be performed on the viewers' reception equipment. When the video server receives a pause request and then a subsequent resume request from one of the viewers, it transmits the video via the look ahead stream instead of the common data stream.

In a preferred embodiment, "look-ahead" stream scheduling with "look-aside" buffering is used to support a larger number of viewers than N_{MAX}. This system avoids the need for backing each viewer by a real video stream capacity from the disk.

If a buffer to store t time units of showing is available, two viewers share the same video stream as long as another stream will become available within t time units. This eliminates the need for a real stream capacity at least for t units of time. Look-ahead scheduling backs up viewers with a future (look-ahead) stream which is currently being used for another showing so he can pause and resume at any time. Before the look-ahead stream becomes available, the pausing and resuming viewing are supported by the original stream through buffering of the missed content. If there is not enough buffer space to support look-ahead scheduling, a reserved stream is used.

A reserved stream is an otherwise unused stream capacity of the server. When a reserved stream is allocated, the useable stream capacity of the multimedia system is reduced by one. With a reserved stream, a viewer who is sharing a common video stream with other viewers can pause at any time. When the viewer resumes, the reserved stream becomes the viewers active stream to be viewed.

At the time when the video showing associated with a look-ahead stream completes, if another playing or reserved stream can be found which will be completed within t units of time, a new look-ahead stream can be designated and the completing look-ahead stream can be used to schedule other viewers. So a viewer may be supported by a sequence of different look-ahead streams during the showing.

Thus each viewer is supported by either the real stream showing the video, some look-ahead stream, or a reserved stream. Each real stream or reserved stream for a given showing can support one look-ahead stream of another showing. There is an additional level of complexity due to the fact

that the viewer of a look-ahead stream may pause so that the actual finishing time can be uncertain. To get around this problem, a stream, once chosen as a look-ahead stream, is not allowed to pause. Instead, when the viewer pauses, the stream is buffered. Then, when the viewer resumes he views the video from the buffer. Once a viewer can get the remaining portion of the video from the buffer, there will be no further stream requirement for the video. The viewer's buffer contents are not released until the viewing is completed.

III. Brief Description of the Drawings

Fig. 1 is a block diagram of a multi-media server;

Fig. 2 is a block diagram of the (look-aside) buffer status;

Fig. 3 shows the stream status table;

Fig. 4 shows a time line for a video request processing example;

Fig. 5 is a flow diagram of an overall view of the look-ahead scheduler of FIG. 1, according to an embodiment of the present invention.

Figs. 6a & 6b are a more detailed diagram of the look ahead scheduler task;

Fig. 7 is a more detailed flow diagram of the pause operation;

Fig. 8 is a more detailed flow diagram of the resume operation;

Fig. 9 is a more detailed flow diagram of the stream completion operation;

Fig. 10 is a more detailed flow diagram of the viewing completion operation;

Fig. 11 is a more detailed flow diagram of the ahead stream switching process.

Like reference numerals appearing in more than one drawing depict like elements.

IV. Detailed Description Of A Preferred Embodiment

FIG. 1 is a block diagram of a video-on-demand system according to an embodiment of the present invention. In the following description, it is assumed that in a video-on-demand system clients 1 make requests from a video server 2 via a communication network 3. The movies (videos) are stored on disks 5. The server 2 includes memory buffers 6 for temporary storage of movies for handling short pause requests. The video server 2 also includes a processor 7 (cpu) which executes tasks under control of a main control program (mcp) 8. The video server can be embodied using any processor of sufficient performance for the number of video streams to be supported. For example, a small capacity video server could be embodied using an RISC System/6000 (RS/6000) system while a larger capacity server could be embodied using an ES/9000 system (both available from International Business Machines Corporation of Armonk, New York). The communication network 3 can be, for example, a fiber optic network. The clients 1 are supported by a set-top box which enables them to send commands to the server 2 by way of the network 3.

In accordance with an embodiment of the present invention, one of the tasks is a look-ahead scheduler 9. The clients can make requests to start, stop, pause and resume a movie. The individual client requests are handled by a client scheduler 40. The look-ahead scheduler 9 attempts to conserve server resources by combining requests for the same movie that are close together in time while allowing each client to individually pause and resume.

The look-ahead scheduler 9 maintains a buffer status table 4 which tracks the use of the memory buffer 6. Referring now to Fig. 2, the (look-aside) memory buffer status

will be described. Each buffer block can be in one of the three states: reserved, in-use, and available. As will be explained in detail later, during scheduling of videos, buffers can be put into a "reserved" state to support pause-resume. A "reserved" buffer changes to an "active" (in-use) state when a video stream is stored into it. The buffers which are neither "reserved" nor "active" are available for future allocation.

The look ahead scheduler also maintains a stream status table 11 which will now be described by reference to Fig. 3. The multimedia server can only support a fixed number of streams. A stream is considered to be "active", if it is supporting an actual showing of a video. A stream is considered "reserved" if it is reserved to support pause-resume of concurrent viewers of a showing. If a stream capacity is neither "active" nor "reserved", it is available for future showing.

Fig. 3 illustrates one way to do the bookkeeping. For each stream, the status of active, reserved or none is recorded. The absence of a recorded status (none) in both the active field 301 and reserved field 302 indicates that the steam is available. For a reserved stream, information on the corresponding active stream showing the video is also recorded in the "reserved" field 302. If a stream is designated as a look-ahead stream for a viewer in another showing being serviced by an active stream, information identifying that active stream is provided in the "look-ahead" field 304. The ID of the video showing on the active stream is recorded in a video ID field 306.

For example, in Fig. 4, assume that three video requests for video A get scheduled at time t_0 and at that moment, there

is no other active stream. Stream 1 is chosen as the active stream and streams 2 and 3 are designated as reserved streams for concurrent viewers on stream 1. (See the reserved field of streams 2 and 3 in Fig. 3.) At time t_1 two video requests for video B get scheduled. Assume that stream 1 is within t units of time to completion and there is sufficient buffer to support stream 1 as a look-ahead stream. We can choose stream 4 as the active stream and use stream 1 as the look-ahead stream. (See Fig 1c on the look-ahead field of stream 1.) Note that this second group of viewers (of video B) are not current viewers of stream 1. They merely use stream 1 (which is currently carrying video A) as a look-ahead stream to support pause-resume operations. Hence, viewers of stream 1 always means the first group of viewers which is currently viewing video A. If another four requests for video C are scheduled immediately afterwards, stream 5 can be used as the active stream and streams 2 and 3 as the look-ahead steams, assuming sufficient buffer. In addition, stream 6 is needed as a reserved stream. (See the look-ahead field of streams 2 and 3 and the reserved field of stream 6 in Fig. 3.) Figure 1c shows the stream status at this point, where there are 9 viewers consuming six stream capacities.

Assume that the multi-media system has a buffer for look-aside purposes of size B and a stream capacity of N_{MAX}. Let N_{RESRV} be the number of reserved streams in the system and N_{ACT} be the number of active streams showing the videos. Let B_{RESRV} be the amount of look-aside buffer reserved and B_{USE} be the amount of look-aside buffer currently in use. We further assume that each unit of time showing requires K bits of data.

Each time a video is selected for showing if N_W customers are waiting for that video, the following procedure determines the largest number of viewers, C, that can be scheduled to

allow for pause-resume. The procedure uses as many look-ahead streams as possible given the buffer constraint, and support the remaining viewers by reserved streams. To be more specific,

1. First the maximum number of additional look-ahead streams supportable given the current buffer usage is determined. This is referred to as N_{LABEAD} and is the minimum of the following two quantities,

   - The number of video streams (not yet marked as look-ahead streams) to be completed in the next t units of time assuming no pausing, where t is a pre-specified operating parameter determined from the amount of buffer space available to support pause-resume. These are the potential look-ahead streams.

   - The number of additional look-ahead streams supportable by the current state of the buffer. Let us order the potential look-ahead streams based on their remaining time to completion, assuming no pausing. From a buffering view point, one would choose look-ahead streams on that order, i.e. choose look-ahead streams based on their completion times. Assuming that the *ith* potential look-ahead stream has a remaining time to completion of $t\alpha_i$, it will need a buffer of size $tK\alpha_i$ to be reserved if chosen. This buffer amount is needed to the save the video contents to completion if the current viewer of the potential look-ahead stream goes into a pause mode. (It is large enough to stream the rest of the showing into buffer, even in the worst case of immediate pausing.) If x look-ahead streams are chosen, an amount of $xtK\alpha$ additional reserved buffer will be needed to handle pausing of their

associated viewers, where αt is the average remaining time to complete for the first x potential look-ahead streams, i.e:

$$\alpha = (\sum_{i=1}^{x} \alpha_i)/x$$

In addition, an amount of tK buffer space needs to be reserved to support short pausing of the new group of viewers (currently waiting to be scheduled) before the look-ahead streams become available. Hence, with x look-ahead streams chosen, the total amount of buffer needs to be reserved is $(tK + xtK\alpha)$. Thus, from the buffer view point the maximum supportable look ahead steams is the largest x value such that the buffer constraint is satisfied.

2. If this maximum number (x) is larger than $N_w - 1$, all of these requesting viewers can be scheduled with one real stream for showing the video, and $N_w - 1$ look-ahead streams. In this case, C equals to N_w.

3. Otherwise, the number of look-ahead streams used is N_{LAHEAD}. We need to obtain some streams capacities to put in reserved mode in order to schedule additional viewers not backed up by the look-ahead streams. The reserved streams obtainable must be smaller than the number of streams available, N_{AVAIL}, which is equal to $N_{MAX} - (N_{RESRV} + N_{ACT})$. If $N_w - N_{LAHEAD} - 1$ streams or more are available to be put into reserved mode, all requested viewers can

still be scheduled, i.e. C equals to N_M. Otherwise, C will be $N_{AVAIL} + N_{LAHEAD}$.

Let D be the number of look-ahead streams used. We will then set B_{RESRV} equal to $tK + DK\alpha + B_{RESRV}$ and increase N_{ACT} by one. Also if reserved streams are used, N_{RESRV} is increased accordingly. Note that B_{USE} will be incremented when the reserved buffers are actually in use to support the pause action. (B_{RESRV} will be decremented for the same amount.) This buffer will be released when not needed.

The buffer constraint in step 1, can be expressed as $\Theta(tK + xtK\alpha + B_{RESRV}) < (B - B_{USE})$, where Θ (theta) is a tuning parameter. Setting Θ equals to one guarantees that the paused viewer will always be able to get back with no delay. In reality, not all viewers are going to pause at the same time, so Θ can be set at a lower value while still maintaining very low probability that the returned viewer would need to wait. Similarly, N_{AVAIL} can be redefined to be $N_{MAX} - (\Theta' N_{RESRV} + N_{ACT})$,

where Θ' is another tuning parameter. Note that in the case of a guaranteed no-delay resume, Θ' is set to one.

The look-ahead streams assigned can be delayed. For an additional ΘtK amount of buffer that can be reserved within the next t units of time, look-ahead streams can be allowed to be available t time units later. This rule can be applied repeatedly.

When a stream which is designated as a look-ahead stream is completed, if another look-ahead stream can be found to replace it (i.e. within t units of time to completion), new viewer requests can be scheduled using the newly available stream capacity. Otherwise it becomes a reserved stream. If a look-ahead stream will become available after t+w units of time, the reserved stream can be replaced by that look-ahead stream after w units of time. It can then be scheduled for other viewing.

Another optimization to improve the throughput is to allow a resuming stream to merge with a later-showing real stream. Still an appropriate look-ahead stream is required as before to support additional pausing in the future.

Referring now to FIG. 5 there is shown a flow diagram of an overall view of a scheduling method according to an embodiment of the present invention. The video request arrival is indicated in step 10. In step 15, the available stream capacity is checked. If there is no available stream capacity, step 20 is executed where the incoming video request is put into a request wait queue. Otherwise, if there is available stream capacity, steps 25-40 are executed. In step 25, the video request or requests is scheduled. The details of the scheduling procedure are given in Fig. 3. Once a video

is scheduled, each viewer can pause and then resume at any time desired as indicated in step 30 for pausing operation and step 35 for resuming. The details of the bookkeeping to support the pause and resume operations are given in Figs. 4 and 5, respectively. Step 40 represents the completion of the viewing by a requester. The details of the operation associated with the viewing completion are given in Fig. 6.

Referring now to Figs. 6a and 6b the details of the scheduling operation are shown in more detail. In step 50, it is assumed that each time a movie is selected for showing, there are N_W customers waiting for that movie. In step 55, the number of available streams that may be marked as look-ahead streams is determined. This is the number of streams, not yet marked as look-ahead streams, that can be completed in the next t units of time assuming no pausing requests. In step 60, the maximum number of look-ahead streams (N_{LAHEAD}) supportable for the given buffer size is determined.

In step 65, N_{LAHEAD} is compared to N_{W-1}. If N_{LAHEAD} is larger than N_{W-1}, all requesters can share one video stream, where another N_W look-ahead streams are used to backup the pausing requirement, as indicated in step 70. In step 75, the number of buffer required to support the look-ahead scheduling is put into reserve mode.

Going back to step 65, if the maximum number of look-ahead streams supportable for the given buffer size is smaller than N_{W-1}, there are not enough look-ahead streams, hence some video stream capacity needs to be put into reserve mode. Step 80 determines the number of video streams that are currently available (i.e. neither showing nor reserved). In step 85, the number of available video streams is compared to

the requirement to support outstanding viewers for the video. If there is enough available video streams, steps 90 and 95 are executed. Otherwise, steps 100 and 105 are executed. In steps 90 and 100, the appropriate number of requesters are scheduled for viewing the video showing, respectively. In steps 95 and 105, the appropriate number of video streams are put into reserved mode, respectively. In step 110, the amount of buffer space required to support the look-ahead scheduling is put into reserve mode. In steps 115 and 120, the bookkeeping on the scheduling is complete.

Referring now to Fig. 7 the details of the pausing operation are shown in more detail. Step 130 indicates the arrival of a pause request at the video server. In step 135, it is checked whether that viewer can be supported by a look-ahead stream. If the viewer can be supported by a look-ahead stream, as indicated by step 140, the reserved buffer is put into use to temporarily buffer the missing contents for the pausing viewer up to t units of time. In step 145, the pausing period is checked. If it exceeds the limit, in step 150 the buffer is released if no other viewers are using it.

If, in step 135, the viewer can not be supported by a look-ahead stream, in step 155 it is further checked if the supporting stream is marked as a look-ahead stream for another viewer. If this is true, in step 160, the video stream will continue streaming the video into the buffer until completion. The stream completion operation indicated in step 170 is explained in Fig. 9. In step 155, if the stream is not marked as look ahead, it can be stopped as indicated in step 175.

Referring now to Fig. 8 we examine the details of the resume operation. In step 200, it is checked whether the resuming point is available in the buffer. If so, as indicated in step 205, the viewer resumes the viewing from the buffer. Otherwise, as indicated in step 210, a reserved stream will be made into an actual showing stream to support the resumed viewer.

Referring now to Fig. 9 the details of the stream completion operation are shown. In step 220, when a video stream is completed, the scheduler determines whether this stream or any other associated reserved stream has been marked as a look-ahead stream. For each stream marked as a look-ahead stream, as indicated in step 230, the scheduler determines whether another stream can be identified and switched into a look-ahead stream. This is addressed in details in Fig. 8. If another stream can be switched to a look-ahead stream, steps 235 and 240 are executed. In step 235, that stream is designated as a new look-ahead stream to replace the completing video stream and in step 240, the completing stream is released as an available stream and the process of scheduling new video requests can be initiated if there are waiting video requests. (the stream scheduling process is described in Fig. 6.) In step 230, if no other stream can be switched into a look-ahead stream, steps 245 and 250 are executed. In step 245, the completing stream is made into a reserved stream, and in step 250, the appropriate bookkeeping is done.

Referring now to Fig. 10 we examine the details of the viewing completion operation. Note that viewing completion can be later than the stream completion, since during pausing, the video stream may continue and be saved in the buffer. In step

280, all buffer space in use or reserved for the completing viewer is released if not needed by another viewer. In step 285, simultaneous stream completion is checked. If so, the appropriate actions depicted in Fig. 6 are performed.

Finally referring now to Fig. 11 the details of the process of switching look-ahead stream will be described. Fig. 8 is a more detailed flow diagram of step 230 of Fig. 6. In step 300, let ϵ (epsilon) be the lag of the look-ahead stream to the actual showing stream. In step 305, the value of epsilon is examined. If it is not equal to zero, in step 310, the amount of available buffer is examined. If there is sufficient buffer (larger than B_{MIN}) after some additional allocation (of the amount of $\Theta tk\epsilon$), steps 315 and 320 are executed. In step 315, that additional buffer allocation is being made, and in step 320, the look ahead interval is set to t. In step 335, it is checked for whether any stream not yet marked as a look-ahead stream can terminate in the next t time units, assuming pausing does not occur. (If so, in step 235, the earliest terminating stream assuming no pausing is chosen as the look-ahead stream to switch over.)

Returning to step 310, if there is insufficient buffer (not larger than B_{MIN}) after some additional allocation (of the amount of $\Theta tk\epsilon$), no additional buffer is reserved and steps 325 and 335 are executed. In step 325, the look ahead interval is set to $t - \epsilon$.

Returning to step 305, if the value of ϵ is equal to zero, steps 330 and 335 are executed. In step 330, the look ahead interval is set to t.

Now that the invention has been described by way of the preferred embodiment, various modifications and improvements will occur to those of skill in the art. Thus, it should be understood that the preferred embodiment has been provided as an example and not as a limitation. The scope of the invention is defined by the appended claims.

CLAIMS

1. A method of supporting pause-resume for a video-on-demand system of a type which can accommodate multiple viewers sharing a common data stream, comprising the steps of:

receiving a performance request from one of the viewers for showing a particular video;

in response to the performance request, identifying and reserving a look-ahead stream, the look ahead stream being another video stream which is scheduled to become available after a predetermined time period;

concurrently transmitting the common data stream from a video server to reception equipment at the multiple viewers' locations, transmission of the data stream causing the particular video to be performed on the reception equipment;

receiving at the video server, a pause request and a subsequent resume request from one of the viewers; and,

in response to the resume request, transmitting the particular video by way of the look ahead stream instead of the common data stream.

2. The method of Claim 1 wherein a different look ahead stream is identified after a period of time as elapsed without the viewer initiating a pause request.

3. The method of claim 1 wherein in response to the performance request the one of the viewers is assigned a reserved stream which is released when the look ahead stream is identified.

4. The method of claim 1 wherein the one of the viewers is allocated sufficient buffer space to buffer the common video stream for a predetermined period of time.

5. The method of claim 1 comprising the further step of buffering video data streams in response to pause requests from the viewers, whereby a number of viewers supportable by a given stream capacity is increased.

6. A system for supporting pause-resume for a video-on-demand system of a type which can accommodate multiple viewers sharing a common data stream, comprising the steps of:

receiving means for receiving a performance request from one of the viewers for showing a particular video;

identifying means, coupled to the receiving means and responsive to receipt of the performance request, for identifying and allocating a look-ahead stream, the look ahead stream being another video stream which is scheduled to become available after a predetermined time period;

transmission means for concurrently transmitting the common data stream from a video server to reception equipment at the multiple viewers locations, transmission of the data stream

causing the particular video to be performed on the reception equipment;

pause/resume means for receiving a pause request and a subsequent resume request from one of the viewers; and,

substitution means, for in response to the resume request, transmitting the particular video by way of the look ahead stream instead of the common data stream.

7. The system of Claim 6 wherein a different look ahead stream is identified after a period of time as elapsed without the viewer initiating a pause request.

8. The system of claim 6 wherein the viewer is assigned a reserved stream which is released when the look ahead stream is identified.

9. The system of claim 6 wherein the substitution means does not transmit the particular video by way of the look ahead stream unless the resume request is received in greater than a predetermined period of time from the pause request and further comprising buffer means for, in response to the pause request, buffering the common video stream for the predetermined period of time and buffer access means, for serving the one of the viewers from the buffer means if the resume request is received within the predetermined period of time.

10. A method of supporting pause-resume for a video-on-demand service of a type which can accommodate multiple viewers sharing a common data stream, comprising the steps of:

receiving a performance request from one of the viewers for showing a particular video;

concurrently transmitting the common data stream from a video server to reception equipment at the multiple viewers' locations, transmission of the data stream causing the particular video to be performed on the reception equipment;

receiving at the video server, a pause request and a subsequent resume request from one of the viewers;

in response to the resume request, performing the particular video for the one of the viewers by commencing transmission of an alternative stream carrying the particular other than the common data stream.

11. The method of claim 10 wherein the particular video is commenced at a point from which the one of the viewers made the pause request.

12. The method of claim 10 comprising the further step of buffering video data streams in response to pause requests from the viewers, whereby a number of viewers supportable by a given stream capacity is increased.

13. The method of Claim 10 comprising the further steps of in response to the performance request, identifying and allocating a look-ahead stream, the look ahead stream being another video stream which is scheduled to become available after a predetermined time period; and, using the look-ahead stream as the alternative stream.

14. The method of claim 10 wherein the alternative is a reserved stream allocated from reserve capacity of the video server.

15. The method of Claim 10 comprising the further steps of assigning buffer space to buffer the common video stream for a predetermined period of time, and when the one of the viewers resumes before the predetermined period of time, serving the one of the viewers the particular video from the buffer space instead of by way of the alternative stream.

FIG. 1

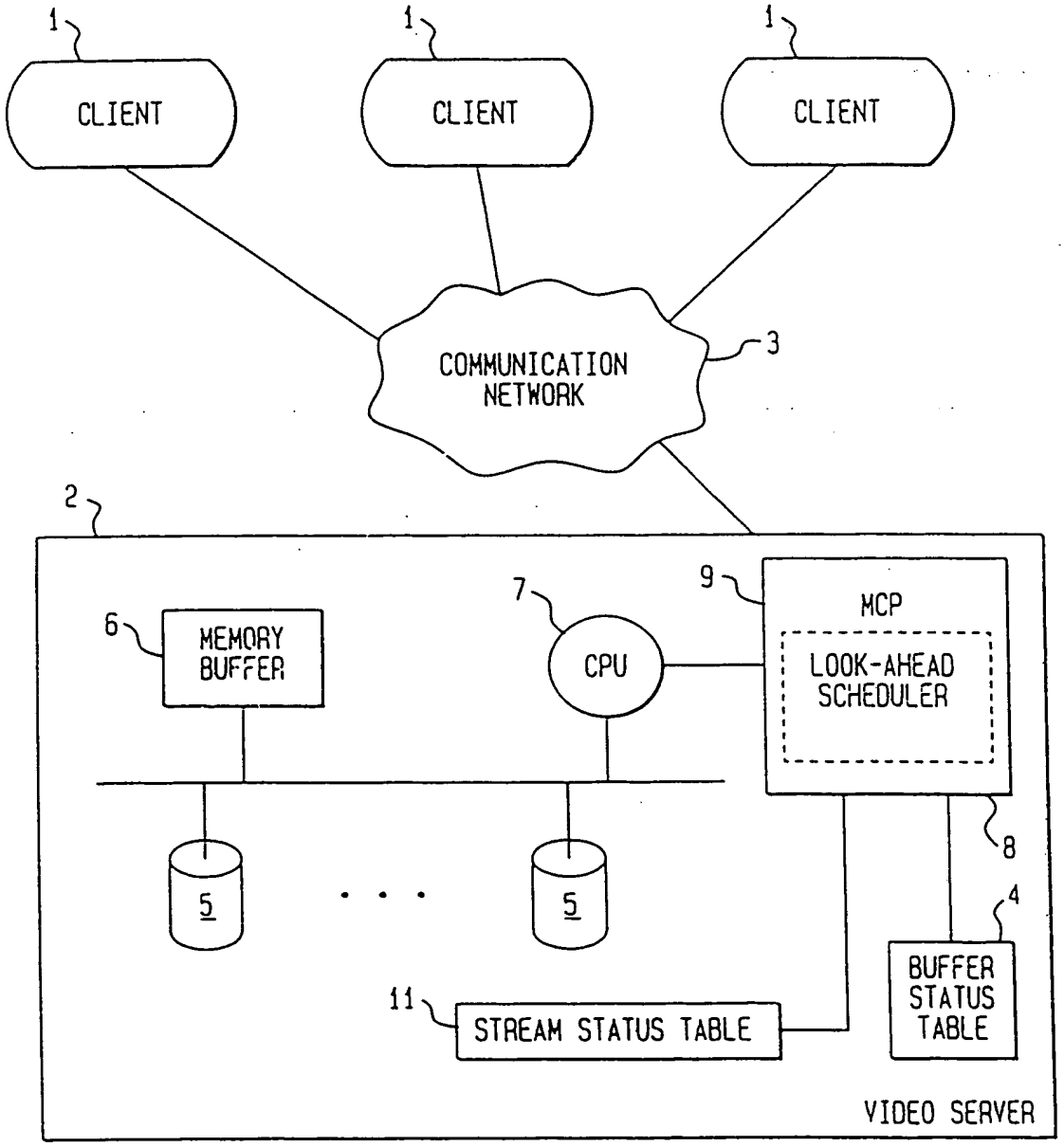

1
CLIENT
1
CLIENT
1
CLIENT
COMMUNICATION NETWORK
3
2
6
MEMORY BUFFER
7
CPU
9
MCP
LOOK-AHEAD SCHEDULER
8
4
5
5
11
STREAM STATUS TABLE
BUFFER STATUS TABLE
VIDEO SERVER

FIG. 2

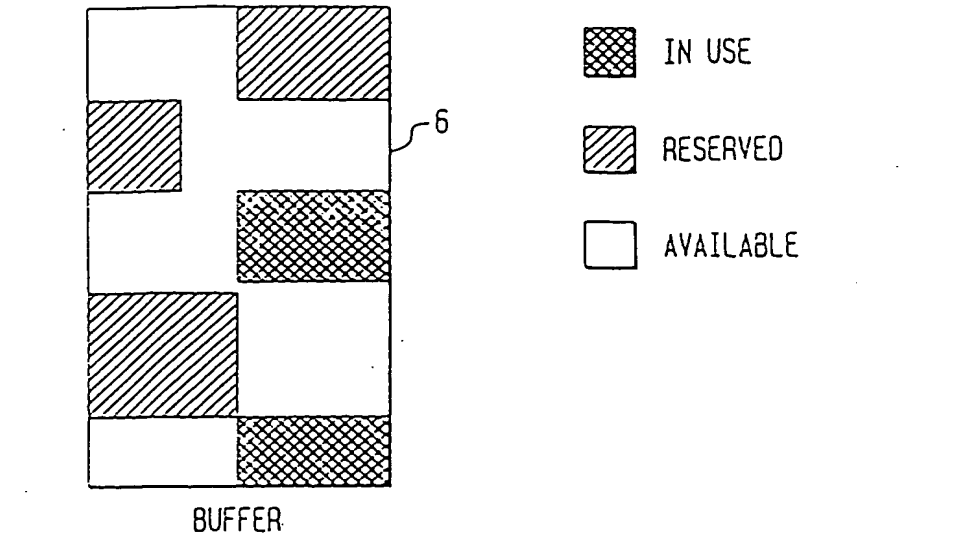


FIG. 3

STREAM ID	ACTIVE (301)	RESERVED (302)	LOOK-AHEAD (304)	VIDEO ID (306)
1	Y		4	A
2		Y 1	5	
3		Y 1	5	
4	Y			B
5	Y			C
6		Y 5		
7				
8				
9				
10				

11

FIG. 4

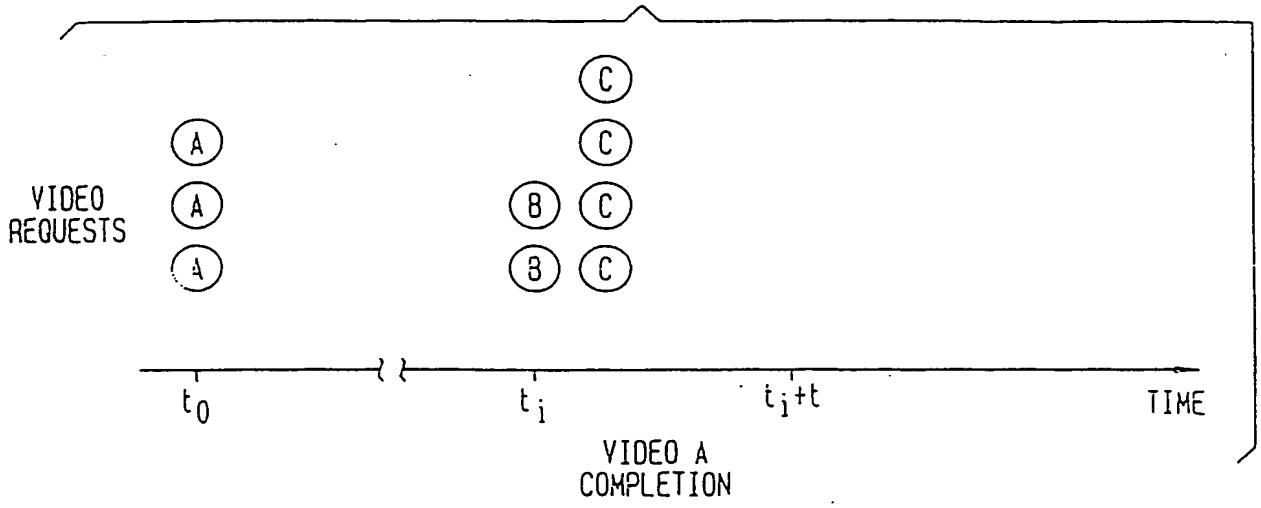

VIDEO REQUESTS
A
A
A
B
B
C
C
C
C
t_0
t_i
t_i+t
TIME
VIDEO A COMPLETION

FIG. 5

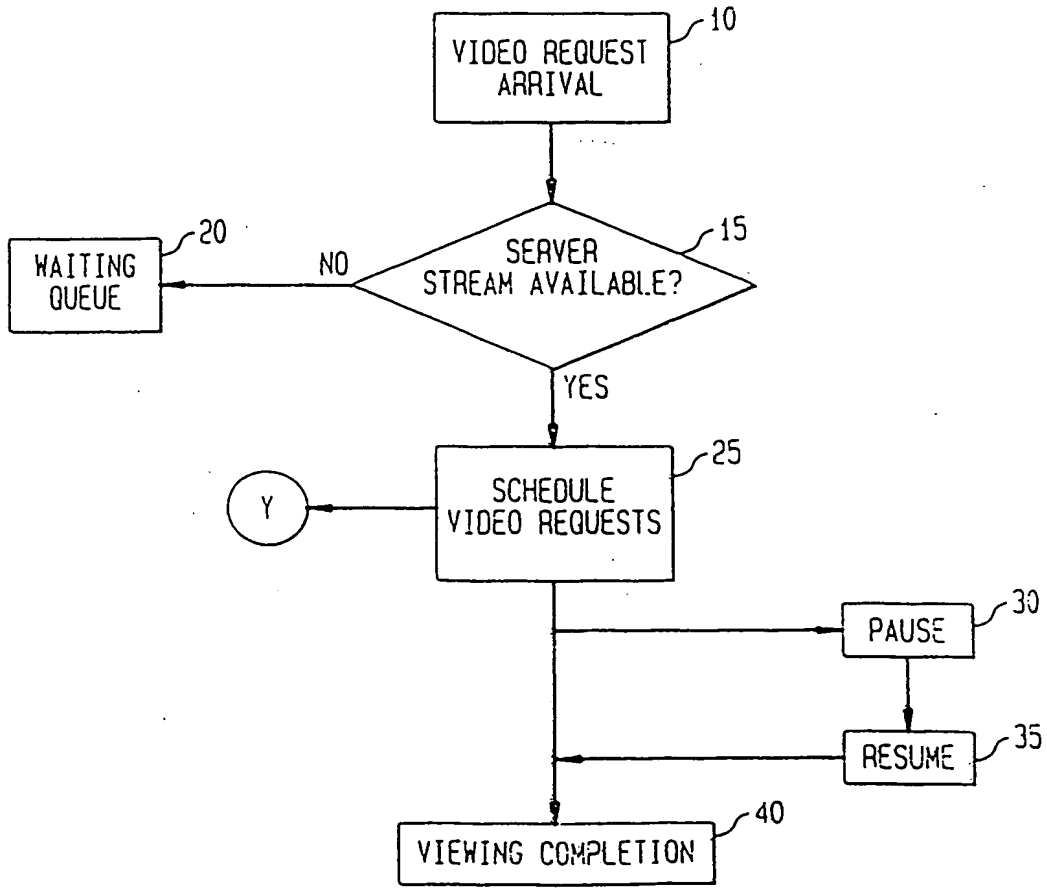

VIDEO REQUEST ARRIVAL
10
SERVER STREAM AVAILABLE?
15
NO
WAITING QUEUE
20
YES
SCHEDULE VIDEO REQUESTS
25
Y
PAUSE
30
RESUME
35
VIEWING COMPLETION
40

FIG. 6A

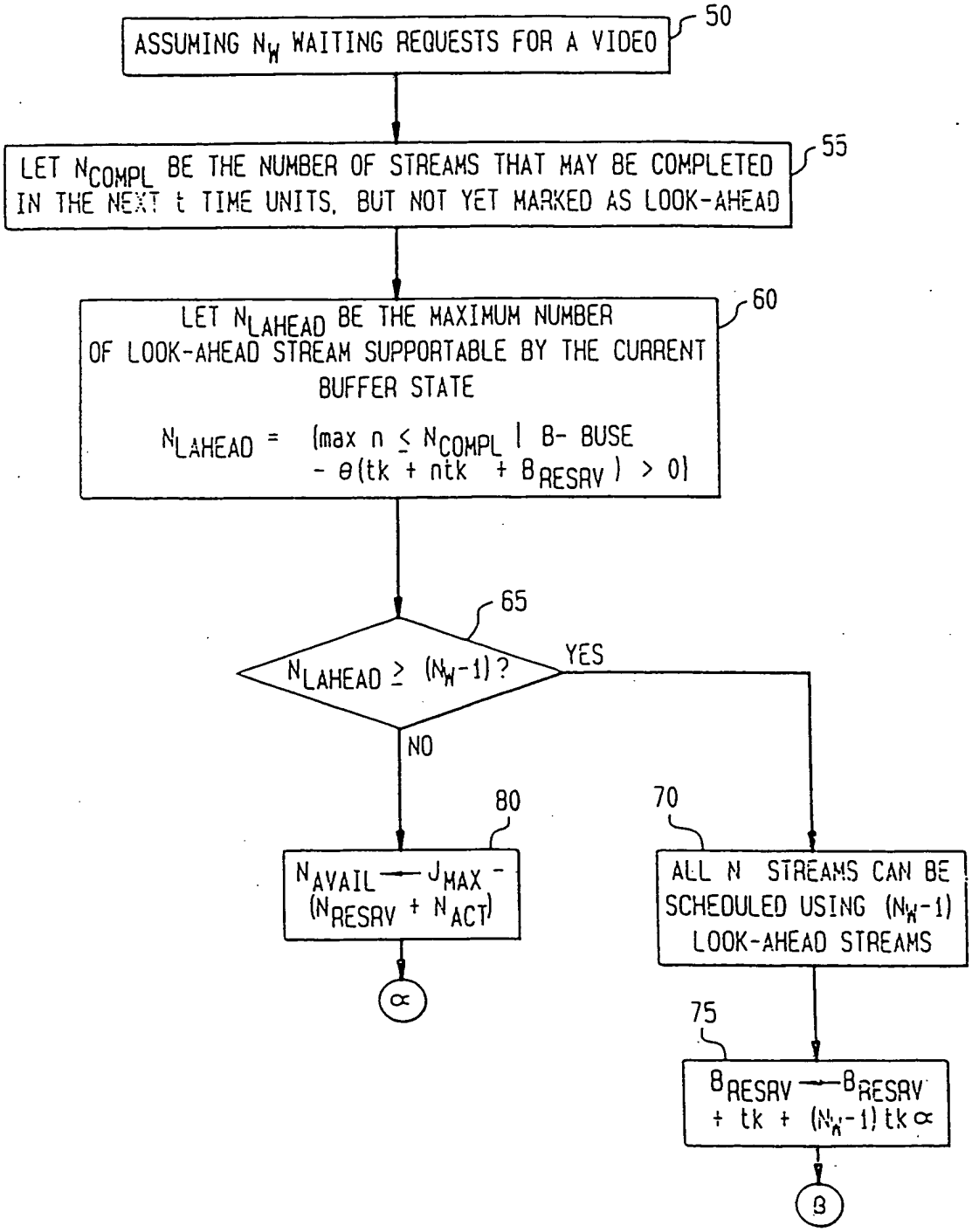

ASSUMING N_W WAITING REQUESTS FOR A VIDEO
50
LET N_{COMPL} BE THE NUMBER OF STREAMS THAT MAY BE COMPLETED IN THE NEXT t TIME UNITS, BUT NOT YET MARKED AS LOOK-AHEAD
55
LET N_{LAHEAD} BE THE MAXIMUM NUMBER OF LOOK-AHEAD STREAM SUPPORTABLE BY THE CURRENT BUFFER STATE
$N_{LAHEAD} = \{\max n \leq N_{COMPL} \mid B - BUSE - \theta(tk + ntk + B_{RESRV}) > 0\}$
60
65
$N_{LAHEAD} \geq (N_W - 1)$?
YES
NO
80
$N_{AVAIL} \leftarrow J_{MAX} - (N_{RESRV} + N_{ACT})$
70
ALL N STREAMS CAN BE SCHEDULED USING $(N_W - 1)$ LOOK-AHEAD STREAMS
75
$B_{RESRV} \leftarrow B_{RESRV} + tk + (N_W - 1)\, tk\, \alpha$
α
β

FIG. 6B

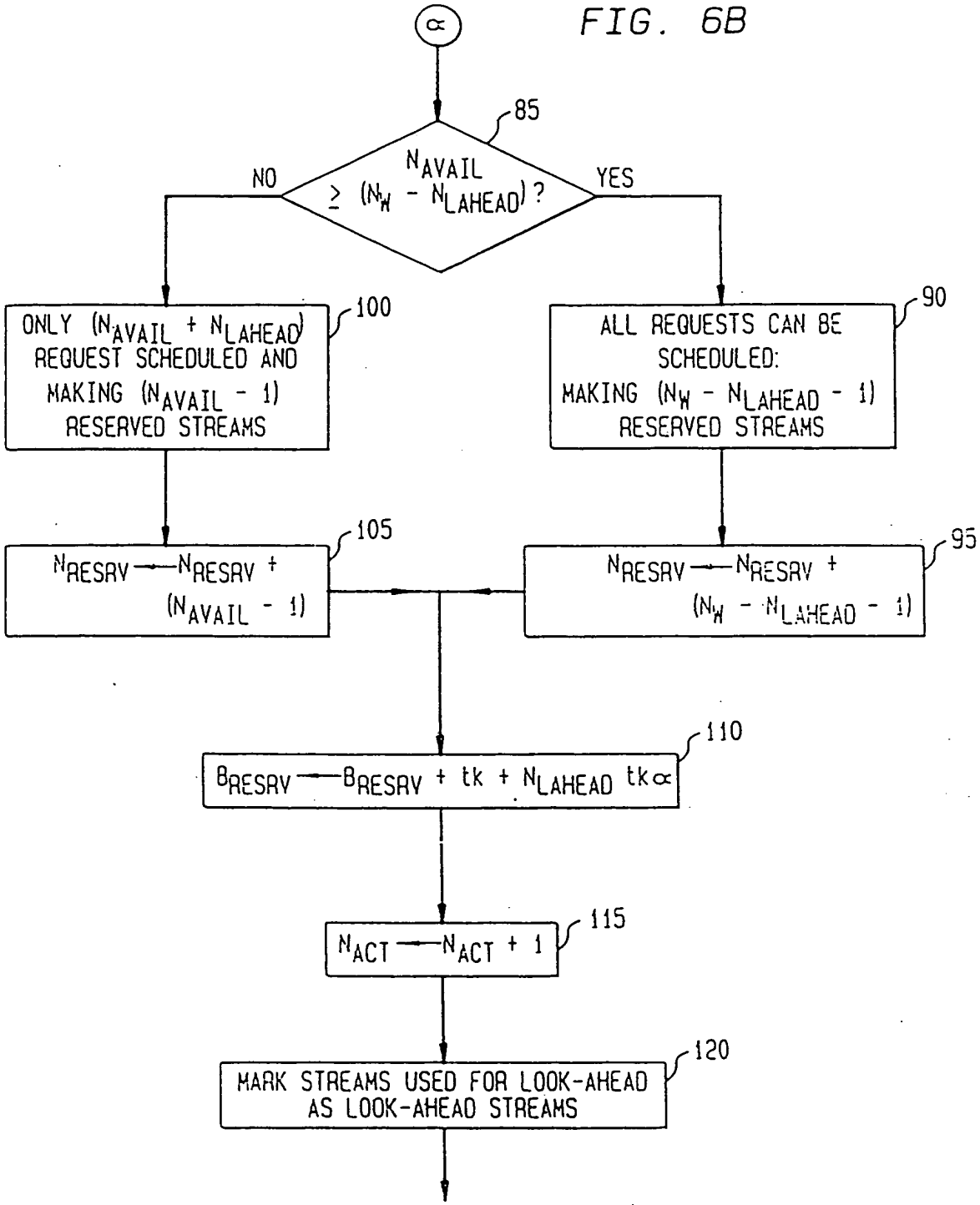

∝
85
$N_{AVAIL} \geq (N_W - N_{LAHEAD})$?
NO
YES
ONLY $(N_{AVAIL} + N_{LAHEAD})$ REQUEST SCHEDULED AND MAKING $(N_{AVAIL} - 1)$ RESERVED STREAMS
100
ALL REQUESTS CAN BE SCHEDULED: MAKING $(N_W - N_{LAHEAD} - 1)$ RESERVED STREAMS
90
$N_{RESRV} \leftarrow N_{RESRV} + (N_{AVAIL} - 1)$
105
$N_{RESRV} \leftarrow N_{RESRV} + (N_W - N_{LAHEAD} - 1)$
95
$B_{RESRV} \leftarrow B_{RESRV} + tk + N_{LAHEAD}\ tk\alpha$
110
$N_{ACT} \leftarrow N_{ACT} + 1$
115
MARK STREAMS USED FOR LOOK-AHEAD AS LOOK-AHEAD STREAMS
120

FIG. 7

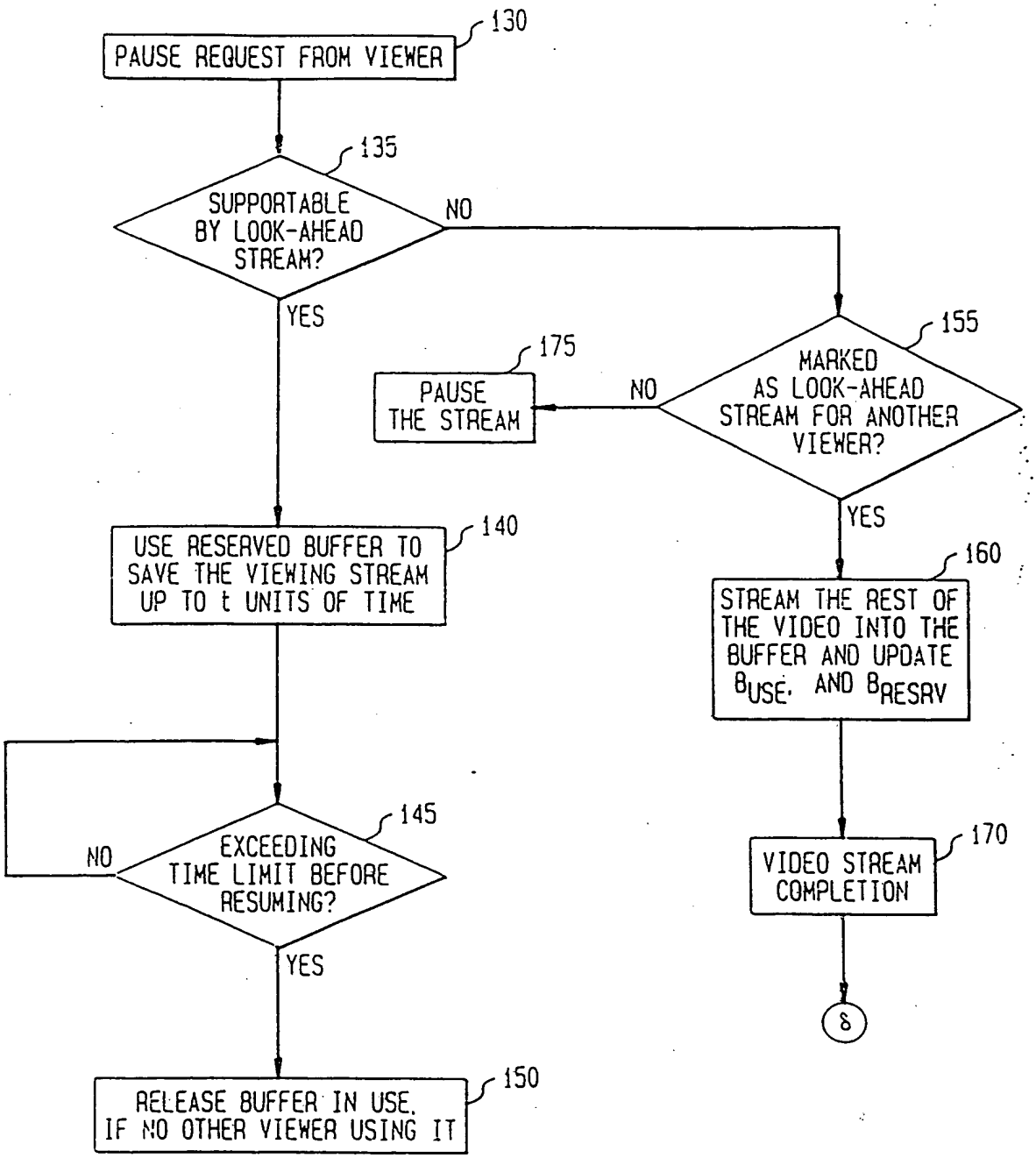

130
PAUSE REQUEST FROM VIEWER
135
SUPPORTABLE BY LOOK-AHEAD STREAM?
NO
YES
155
MARKED AS LOOK-AHEAD STREAM FOR ANOTHER VIEWER?
175
PAUSE THE STREAM
NO
YES
140
USE RESERVED BUFFER TO SAVE THE VIEWING STREAM UP TO t UNITS OF TIME
160
STREAM THE REST OF THE VIDEO INTO THE BUFFER AND UPDATE $B_{USE.}$ AND B_{RESRV}
145
EXCEEDING TIME LIMIT BEFORE RESUMING?
NO
YES
170
VIDEO STREAM COMPLETION
8
150
RELEASE BUFFER IN USE, IF NO OTHER VIEWER USING IT

FIG. 8

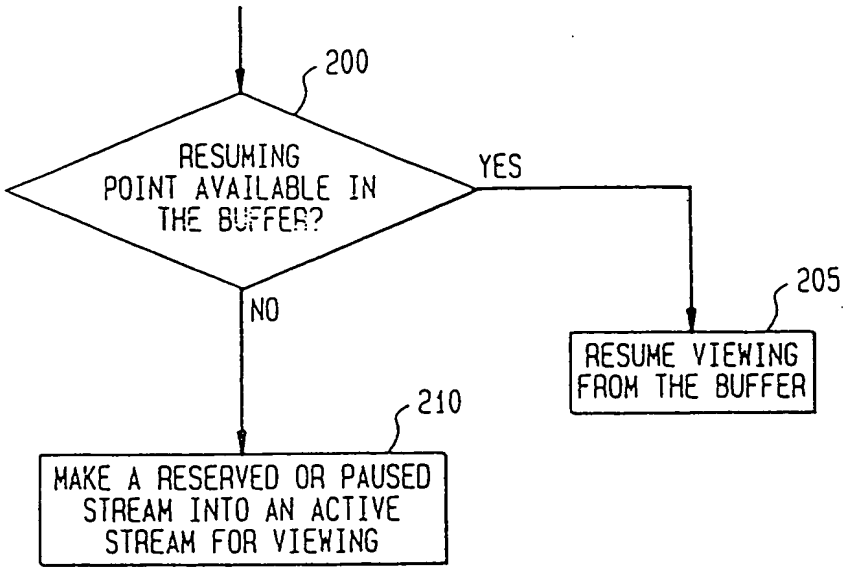

200
RESUMING POINT AVAILABLE IN THE BUFFER?
YES
NO
205
RESUME VIEWING FROM THE BUFFER
210
MAKE A RESERVED OR PAUSED STREAM INTO AN ACTIVE STREAM FOR VIEWING

FIG. 9

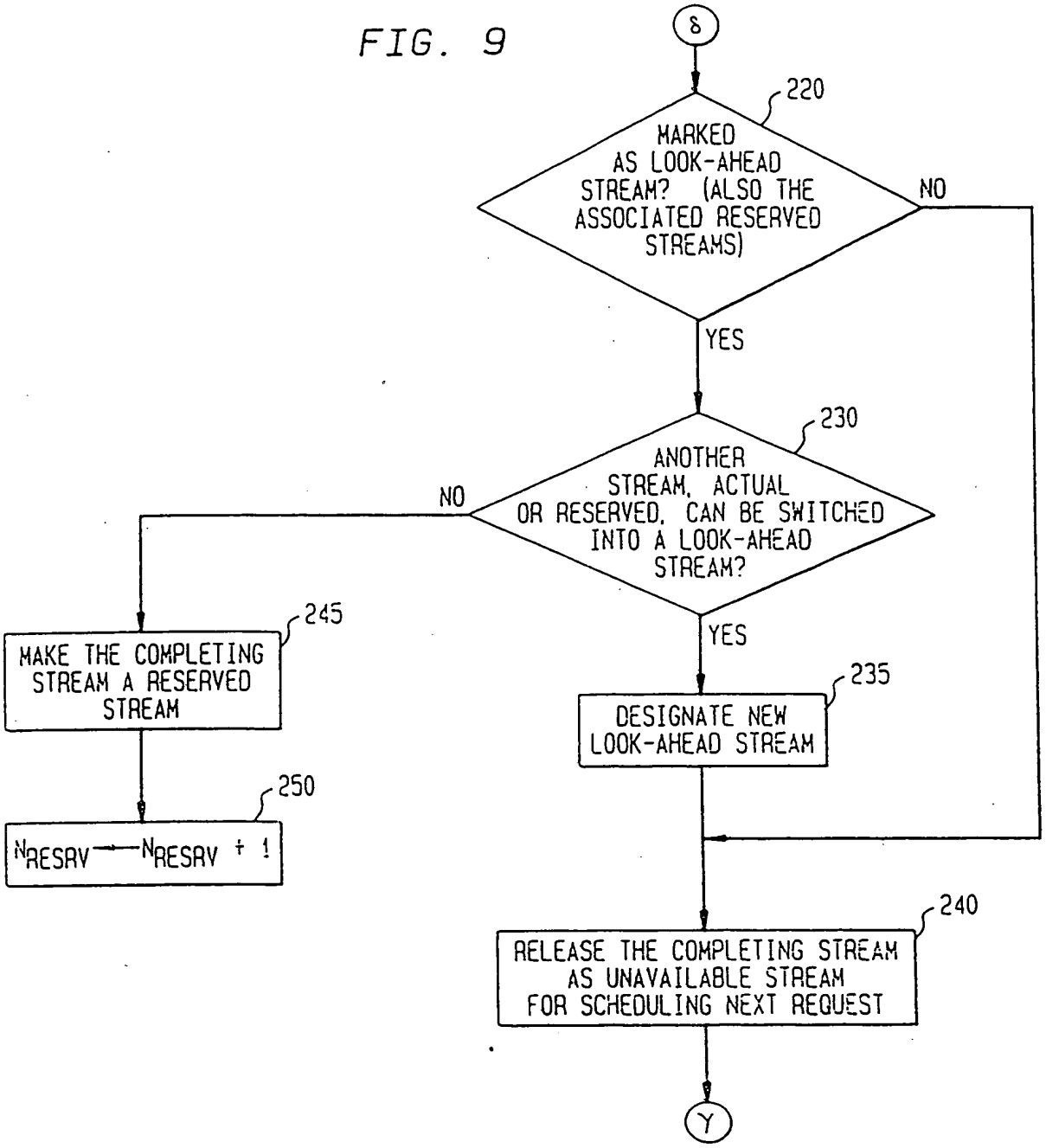

8
220
MARKED AS LOOK-AHEAD STREAM? (ALSO THE ASSOCIATED RESERVED STREAMS)
NO
YES
230
ANOTHER STREAM, ACTUAL OR RESERVED, CAN BE SWITCHED INTO A LOOK-AHEAD STREAM?
NO
YES
245
MAKE THE COMPLETING STREAM A RESERVED STREAM
235
DESIGNATE NEW LOOK-AHEAD STREAM
250
NRESRV ← NRESRV + 1
240
RELEASE THE COMPLETING STREAM AS UNAVAILABLE STREAM FOR SCHEDULING NEXT REQUEST
Y

FIG. 10

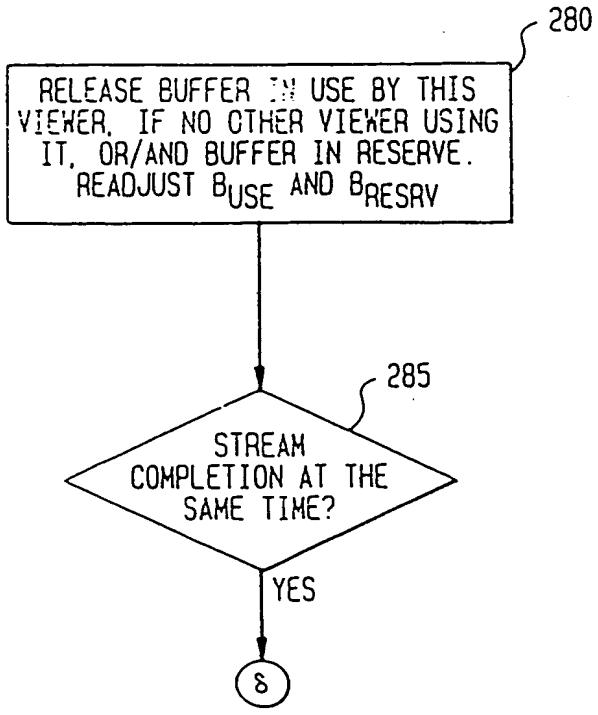
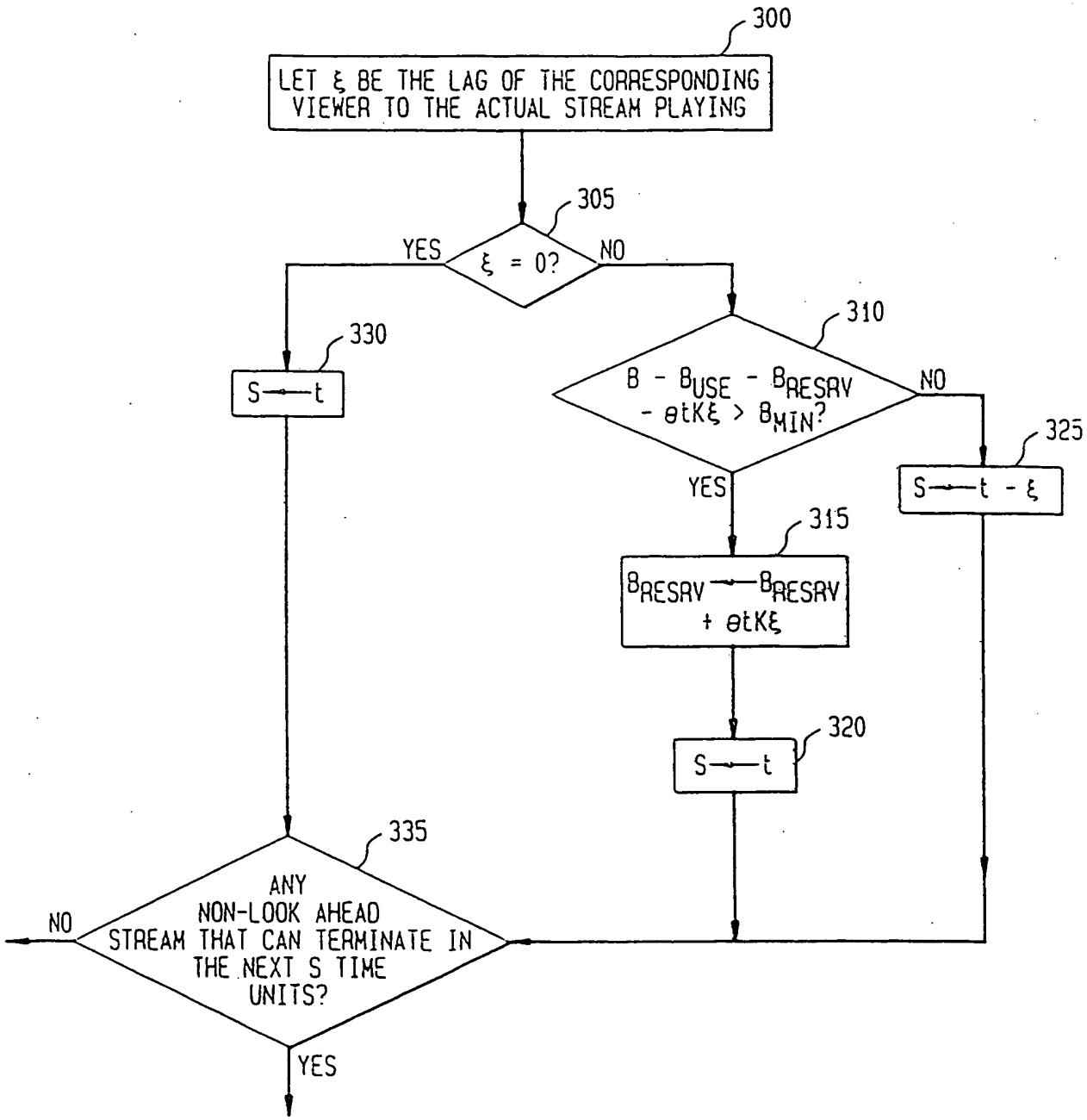

280
RELEASE BUFFER IN USE BY THIS VIEWER. IF NO OTHER VIEWER USING IT, OR/AND BUFFER IN RESERVE. READJUST B_{USE} AND B_{RESRV}
285
STREAM COMPLETION AT THE SAME TIME?
YES
8

FIG. 11


300
LET ξ BE THE LAG OF THE CORRESPONDING VIEWER TO THE ACTUAL STREAM PLAYING
305
ξ = 0?
YES
NO
330
S ← t
310
B - B_USE - B_RESRV - θtKξ > B_MIN?
NO
325
S ← t - ξ
YES
315
B_RESRV ← B_RESRV + θtKξ
320
S ← t
335
ANY NON-LOOK AHEAD STREAM THAT CAN TERMINATE IN THE NEXT S TIME UNITS?
NO
YES